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SOME ANOMALIES IN THE GESTATION OF THE ALBINO RAT (MUS NORVEGICUS ALBINUS).

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In the course of a series of inbreeding experiments with the albino rat which have been in progress for several years, records have been made of the births of over 700 litters containing some 5,000 individuals. These records show a number of striking irregularities in gestation which are deemed worthy of note, since at the present time the albino rat is extensively used as a laboratory mammal in many of the large institutions of the country.

As the data given in this paper form part of the permanent records on file at The Wistar Institute, it has seemed advisable to refer to individual rats by the numbers that will identify them on the record cards, instead of employing some conventional lettering. The scheme for designating the rats, which is outlined below, has been found very satisfactory for keeping track of a large number of individuals, since it tells at once the pedigree of any particular animal. In the scheme of marking used the serial letter, *A* or *B*, indicates that the individual was a descendant of one or of the other of the two females, *A* and *B*, with which the experiments were started in the spring of 1909. The serial letter is preceded in all cases by a number which shows the generation to which the rat belonged. An index number, following the serial letter, indicates in which of its mother's litters the animal was born: if no index number is present the rat was a member of its mother's first litter. The subscript following the serial letter is the number that serves to distinguish each particular rat from the other individuals belonging to the same generation and litter group. An illustration of this method of designating the

rats will, perhaps, make the scheme somewhat clearer. $6B_{57}^{2}$ for example, denotes a female belonging to the sixth generation of rats that descended from female *B*. She was a member of the second litter borne by her mother, and her individual number in the series of rats belonging to the second litters of the sixth generation was 57.

It is part of the daily routine work in the rat colony to examine the cages containing breeding animals and to record the births of litters. The birth of a litter is ascribed to the day on which the litter is discovered, unless it is evident from the appearance of the young rats that their birth had been overlooked at a previous visit. In the latter case an approximate date is assigned for the birth of the litter, and on the record cards this date is followed by an interrogation mark. As the rat colony is usually visited in the morning it is very probable that, in the majority of cases, a litter is discovered shortly after its birth, since observations made at various times indicate that in the rat parturition occurs most frequently in the morning, although it may take place at any time during the day. All of the dates of the births of litters given in the present paper are correct within a few hours, since no cases have been included in which a litter was obviously more than a day old when discovered.

As a rule the male is removed from the breeding cage just before, or immediately after, the birth of a litter in order to guard against the possibility of his destroying the young rats. This is seemingly a needless precaution, since infanticide is comparatively rare in albino rats, although it is very common among brown rats kept in captivity according to the observations of Miller ('11). When young albino rats are destroyed it is done, as a general thing, by the female, either because her nest is disturbed during parturition or because she is not in a physical condition to suckle her offspring and is annoyed by their attempts to obtain food. In only one case, as yet, have I found a male eating the young, and in this instance the female was equally as guilty as her mate.

The anomalies in gestation that are noted in the present paper are of three kinds: (1) Prolongation of the period of gestation; (2) cases of superfecundation; (3) cases of superfœtation.

1. Prolongation of the Period of Gestation.

According to a series of unpublished records kindly furnished me by Dr. J. M. Stotsenburg, of The Wistar Institute, the time between the copulation of a non-lactating albino rat and the birth of her litter varies from 21 days and 15 hours to 22 days and 16 hours. The normal period of gestation for the albino rat, therefore, can roughly be estimated at from 21 to 23 days. In the brown rat kept in captivity the period of gestation seems to be somewhat longer than in the albino rat, as Miller found that it varies from 23½ days to 25½ days in different cases.

Daniel's ('10) investigations show that in the mouse the period of gestation, which is normally 20 days, is considerably prolonged if the female is suckling young. From data obtained in ten cases he formulates the following law: "The period of gestation, in lactating mothers, varies directly with the number of young suckled." In the course of my experiments records have been made of the births of 31 litters borne by lactating albino rats. These records, as shown in the three following tables, indicate that the length of the period of gestation is affected by the number of young suckled and by other factors as well.

Table I. shows the length of the period of gestation when lactating females were suckling five or less young and carrying five or less young.

Table I.

Number of Female.	Date of Birth, First Litter.	No. Young Suckled.	Date of Birth, Second Litter.	No. Young Born.	Gestation Period, Days.
$5A_{2}$	July 14	3	Aug. 8	5	21
$2A_{1}^{2}$	Aug. 26	4	Sept. 9	5	21
$5A_{27}$	Dec. 28	5	Jan. 18	4	21
$7A_{78}$	June 21	5	July 13	5	22
$4A_{18}$	May 23	4	June 6	3	23
$8A_{8}$	Aug. 14	4	Sept. 9	5	23
$5A_{88}$	Nov. 15	5	Dec. 8	3	23
$4B_{24}$	June 14	5	July 7	5	23

In each of the eight cases cited above the period of gestation can be considered as normal since it did not exceed 23 days. It appears, therefore, that the period of gestation in lactating albino rats is not extended if the number of young suckled and the number of young in the second litter does not exceed five in either case.

In Table II. are given the data for cases in which the number of young suckled was five or less while the number of young in the second litter exceeded five.

TABLE II.

Number of Female.	Date of Birth, First Litter.	No. Young Suckled.	Date of Birth, Second Litter.	No. Young Born.	Gestation Period, Days.
$2B_1^2$	June 8	3	June 29	7	21
$1B_1$	Jan. 15	3	Feb. 5	8	21
$6A_{12}$	April 24	5	May 17	8	23
$4B_{13}$	June 2	4	June 26	6	24
$4A_{10}$	Dec. 20	4	Jan. 14	7	25
$5A_{14}$	Nov. 20	4	Dec. 14	9	25
$8B_{20}$	Aug. 20	3	Sept. 15	13	26
$5B_4^2$	Aug. 30	3	Sept. 26	8	27
$4B_{23}$	Aug. 3	4	Aug. 30	8	27
$3A_3$	Jan. 15	4	Feb. 12	7	28
$5B_2^2$	Sept. 11	5	Oct. 10	12	29

In eight of the eleven cases shown in Table II. the period of gestation was prolonged from one to six days. In the three remaining cases the gestation period was normal since it did not exceed 23 days. These results indicate that, as a rule, the period of gestation is prolonged when a lactating female, suckling a small number of young, is carrying a litter containing six or more embryos.

Table III. shows the length of the period of gestation in lactating females suckling more than five young.

TABLE III.

Number of Female.	Date of Birth, First Litter.	No. Young Suckled.	Date of Birth, Second Litter.	No. Young Born.	Gestation Period, Days.
$5A_{13}$	Dec. 8	7	Jan. 2	6	25
$5A_4$	Nov. 25	7	Dec. 20	8	25
$7A_{18}$	Sept. 11	6	Oct. 7	3	26
$5B_1$	July 4	6	July 30	9	26
$4B_{20}$	July 13	6	Aug. 8	10	26
$8A_{15}$	Sept. 16	6	Oct. 13	5	27
$8A_9$	Sept. 13	7	Oct. 11	5	28
$5B_{12}$	Oct. 5	8	Nov. 5	8	30
$8B_{27}$	June 1	10	July 1	8	30
$8A_{11}$	Sept. 13	9	Oct. 14	4	31
$4B_{21}$	July 26	11	Aug. 28	12	33
$6B_{5_7}^2$	May 24	9	June 27	12	34

Since in the twelve cases recorded in Table III. the period of gestation ranged from a minimum of 25 days to a maximum of

34 days it is evident that the suckling of more than five young prolongs the period of gestation in the albino rat. The length of the gestation period is not, as a rule, directly proportional to the number of young suckled. For, assuming 22 days to be the average length of the gestation period, only three of the twelve cases fulfill the conditions of Daniel's law. In the majority of cases shown in Table III. the length of the period of gestation seems to have been little affected by the number of young in the second litter. For instance, female $7A_{76}$, with six young in her first litter, had a gestation period of 26 days before the birth of a second litter containing three individuals; on the other hand, females $5B_1$ and $4B_{40}$, each suckling six young, also had gestation periods of 26 days when there were nine and ten young respectively in their second litters. In some few cases, however, the gestation period seems to be further prolonged if a lactating female is carrying a very large litter. This is indicated by the fact that the two longest gestation periods yet recorded, 33 and 34 days, were found only when the second litter contained an unusually large number of individuals.

The data given in the above tables show that the period of gestation in lactating albino rats varies from a minimum of 21 days to a maximum of 34 days. The length of the gestation period seems to depend, primarily, on factors that affect the nutritive conditions of the embryos, but it is also influenced, to some extent, by the individual peculiarities of the females. Lactating females may have different periods of gestation when the number of young in each of their litters is the same, as is shown in the case of females $3A_3$ and $4A_{39}$. Each of these females had four young in her first litter and seven young in her second litter, yet the former had a gestation period of 28 days before the birth of her second litter, while in the latter female the gestation period was only 25 days.

A comparison of the data given in Table II. with that shown in Table III. indicates that in different lactating females the period of gestation is not as extended when five or less young are suckled as when this number is exceeded. This rule seems to apply equally well also to the different litters borne by the same female. Female $7A_{76}$, when suckling five young, had a

gestation period of 22 days before the birth of a second litter containing five young; when suckling a litter of six the period of gestation was prolonged to 26 days although there were but three young in the second litter. Why the suckling of six instead of five young should invariably prolong the period of gestation is not at all clear. Records of some 800 litters of albino rats show that the average number of young in a litter is six. Seemingly, therefore, the length of the gestation period is prolonged when the number of young suckled equals or exceeds the number that represents the average size of the litter in the species.

Female $6B^{\frac{2}{57}}$ had a gestation period of 34 days, the longest period so far observed. This case is rather an interesting one. The nine young born on May 24, 1912, were suckled until June 20, when it was noticed that the female was pregnant. As the young rats were well developed and able to care for themselves they were removed from the cage, although, under ordinary conditions, a litter is allowed to remain with its mother for a month. The female was watched closely, and parturition was found to take place on the morning of June 27. There was thus a period of one week after the removal of the first litter before the second litter was born, although the normal period of gestation had been passed before the first litter was taken away. Had the young rats in the second litter reached the proper stage of maturity for birth when the first litter was removed it is very probable that they would have been born immediately. In this instance, therefore, lactation did not merely delay parturition but it must have retarded the development of the embryos.

The young rats in the second litter were examined shortly after their birth. They were normal in appearance, but they were very small, weighing not more than 4 gm. each. According to Donaldson ('06), the weight of the albino rat at birth varies from 4.2 gm. to 6.5 gm. As the size of the newborn rat depends to a very considerable extent on the number of individuals in the litter, no significance can be attached to the fact that in this very large litter the rats at birth weighed less than 4.2 gm. each. As it was not considered advisable to allow the female to suckle so many young (12), six of them were killed at once. The others developed normally, and opened their eyes at the usual

time, *i. e.*, when 15 days old. The prolonged period of gestation did not make these young rats more precocious in any way as far as could be determined.

In the rat, as in the mouse according to the observations of Sobotta ('95) and of Long and Mark ('11), ovulation followed by copulation must normally take place within a few hours after parturition, since in all of the cases recorded in the above tables the male was removed shortly after the birth of the litter and the female with her young occupied a cage inaccessible to the entrance of other rats. In none of the cases cited in Table I. could lactation have delayed ovulation, since in each instance the period of gestation was of normal length. The manner in which the experiments were conducted seems to preclude the possibility that the prolonged periods of gestation found in many cases were due to a delay in ovulation caused by lactation, since presumably mammalian spermatozoa are not functionally active for more than two or three days after insemination, although, according to Schultze ('66), they can live in the uterus for as much as six days. It seems probable, therefore, that lactation prolongs the period of gestation by influencing the nutritive conditions of the developing embryos. In the lactating albino rat the physiological conditions affecting nutrition seem to be so adjusted that the suckling of a small number of young does not interfere at all with the development of a second litter which also contains a small number of young. When the number of rats suckled equals or exceeds the number that represents the average size of the litter in the species, then lactation appears to lessen the amount of nourishment that the developing embryos receive. It seems to be more essential for the welfare of the species that the suckling young should be well nourished than that the fœtal young should develop at the normal rate. When a pregnant female is suckling a large number of young, the embryos receive less nourishment than is usually given by a non-lactating mother and consequently they develop more slowly. In cases of this kind the period of gestation is prolonged until the embryos have reached the proper stage of maturity for birth. When a female is suckling a small number of young and carrying a large litter, there is apparently no readjustment of the nutritive conditions

so that each fœtus will get the nourishment that will enable it to develop in the usual time. The development of ten or of a dozen embryos on nourishment normally used by six means, necessarily, that the embryos will develop more slowly and therefore that the period of gestation will be prolonged.

The causes that determine whether the period of gestation in non-lactating albino rats shall be 21 days or 23 days are as yet unknown. Presumably the size of the litter is a determining factor in these cases as well as in those in which a female is already suckling young. The age and physical condition of the female are also factors that are probably of importance in this regard. A very young female or one in poor condition would not be able to nourish her fœtal young as well as would a more mature female in good condition, consequently the period of gestation would tend to be longer in the former case than in the latter.

The extension of the period of gestation in the albino rat from 21 days to 34 days is not a remarkable phenomenon, since the early observations of Tessier, quoted in detail by Collins ('86), show that the duration of the gestation period in various mammals is subject to considerable variation.

The data furnished by Collins and Daniels give the extremes of gestation periods shown in Table IV.

TABLE IV.

Mammal.	No. Cases Observed.	Shortest Period of Gestation, Days.	Longest Period of Gestation, Days.	Difference Between the Extremes, Days.
Cows	575	240	321	81
Mares	447	287	419	132
Sheep	912	145	156	11
Swine	25	109	133	24
Rabbits	161	27	35	8
Mice	10	20	30	10

In none of these cases is the duration of the gestation period relatively as long as in some of the cases recorded in Table III., where the gestation period for the albino rat is shown to have been extended more than one half of the minimum normal period. The relatively greater length of the gestation period in the rat may not, however, be of any significance, since it is very probable that the periods of gestation given in Table IV. are not the longest

that have been observed in the various mammals mentioned, although I have not been able to find any records that exceed them.

2. Cases of Superfecundation.

As there is much confusion in literature regarding the use of the words superfecundation and superfœtation, it seems advisable to define these terms as they are employed in this paper. Superfecundation is used in cases where two or more ova belonging to the *same* period of ovulation were fertilized by successive matings. Superfœtation, on the other hand, is applied to cases in which ovulation, followed by copulation, occurred during pregnancy and led to the simultaneous development in the uterus of two sets of ova belonging to *different* periods of ovulation.

Although no observations have been recorded regarding the time required for parturition by the rat it is generally assumed that all members of a given litter are born within five or six hours, as is the case in the mouse according to the investigations of Long and Mark and of Daniels ('12). While this rule doubtless holds good in the great majority of cases there are occasional exceptions, as is shown by the following instance.

Female $8B_8$ gave birth to a litter on April 8, 1912. It became necessary to move the mother and young the day after the litter was born. Six young rats were transferred to the new nest and all of them were apparently of about the same size and weight. Three days later the new nest was examined to see if the transference had caused the female to destroy her offspring. This time eight individuals were found in the litter; two of them were decidedly smaller than the rest and they had the appearance of having been born but a very short time. In this instance there was an interval of at least two days between the birth of the first six members of the litter and of the last two.

On examining litters of albino rats that are from six to fourteen days old one occasionally finds that one or more of the young rats are decidedly smaller and more immature than the others. Such small individuals have been considered by many investigators as runts, and their size has been attributed to the fact that, being constitutionally weaker, they were unable to obtain

as much nourishment as the other members of the litter and so had not grown as rapidly. The litter of $8B_5$, described above, shows that in some cases the very great difference in the size of the various individuals in a young litter is not due to constitutional weakness on the part of the smaller individuals, but to the fact that the smaller rats were born two or three days after the larger ones.

In the course of my experiments I have found a number of litters, about two weeks old, in which one or more of the individuals were much smaller than the rest. Two instances will serve as examples of such cases. Female $4B_{39}$ gave birth to a litter on October 27, 1911. When the litter was fourteen days old it was examined and found to contain twelve individuals. Ten of the young rats were in a similar condition of development; they weighed from 13.7 gm. to 14.4 gm. each; they were well covered with hair; and their eyes were beginning to open. The other two members of the litter appeared normal in every way; but their eyes were closed; they had comparatively little hair; and they weighed only 9.1 gm. and 9.3 gm. respectively. Judging from their appearance these small individuals were not more than ten days old.

A litter belonging to female $5B_{19}$ was inspected thirteen days after its birth. Nine of the ten young were in approximately the same stage of development, and they weighed from 16.2 gm. to 17.1 gm. each. The tenth individual seemed normal and well nourished, but it weighed only 10.8 gm. and appeared more immature in every way than did the other members of the litter.

The small individuals in both of these litters were earmarked in order to make their identity certain, and they were allowed to grow up. At the end of two months there was no perceptible difference, either in size or in general behavior, between these individuals and the other members of the litter. The relatively small size of these rats when they were two weeks old did not mean, therefore, that they were constitutionally weaker than their fellows but that they were born later.

In litters of albino rats, especially if the litter is very large, it is not uncommon to find individuals that are less vigorous than the other members and that are stunted in their growth.

An instance recently came under my observation in which a male rat in a litter about three months old weighed only 60 gm., while his brothers and sisters all weighed from 130 gm. to 190 gm. each. This small individual was unquestionably a runt, and he was far less vigorous and active than the other rats in the litter. Runts that are found in litters about two weeks old appear *fully as mature* as do the other members of the litter, but they are much less active. In litters like those described above the smaller individuals are always *less mature* than the other rats, although equally as vigorous and well nourished.

In cases of this kind all members of the litter must have developed from ova belonging to the same period of ovulation, since it is very improbable that a second period of ovulation ever follows immediately after the first. There are two possible explanations for these cases. If at some period of ovulation one or more of the ova were unusually slow in maturing they might not be liberated until two or three days after the rupture of the more mature follicles, and so would not be fertilized at the first mating. Such ova might, however, be fertilized at a subsequent mating; for the period of heat in the rat extends over several days and copulations take place frequently during this time, as the investigations of Miller have shown. As the minimum gestation period in the albino rat is 21 days, ova that were fertilized late could not reach the proper stage of maturity to be born with the embryos that developed from the first ova fertilized, and consequently there would be a considerable interval between the births of different members of the litter. According to this explanation such litters are good examples of superfecundation.

There is another possible explanation for these cases, namely, that all of the individuals in the litter were developed from ova that were fertilized at the same mating, but that for some reason, possibly on account of faulty implantation, some of the embryos received less nourishment than the rest and so reached maturity later. Such conditions, it seems to me, would tend to produce runts, and not merely to retard normal development.

On dissecting pregnant females one frequently finds one or more embryos that are much smaller than the rest. While in some instances such small embryos appear normal and are presumably

either runts or embryos that have resulted from superfecundation, in the majority of cases they are pathological, probably because of faulty implantation of the ova. If such pathological embryos are ever born with the rest of the embryos they are destroyed at once by the mother, as they are never found among the normal newborn young.

3. Cases of Superfœtation.

It has been maintained by many physicians that ovulation does not occur during pregnancy and therefore that the conception of a second fœtus by a pregnant woman is impossible. Cases seemingly those of superfœtation have been ascribed to the presence of a bifid uterus, or they have been assumed to be the result of a twin pregnancy in which one fœtus was blighted. Undoubtedly many so-called cases of superfœtation can properly be attributed to one or to the other of these causes, but there are a number of well-authenticated cases, such as those cited by Bonnar ('65), which seem explicable only on the assumption that superfœtation can occur in woman under exceptional conditions.

In the lower mammals superfœtation is seemingly of rare occurrence. An examination of the evidence shows that many cases that have been reported as due to superfœtation are unquestionably instances of superfecundation or of blighted ova. A very probable case of superfœtation in sheep was reported by Arrowsmith in 1834, while the observations of Christopher ('86) show that in the cat ovulation can occur during pregnancy and, therefore, that superfœtation in this species is possible, although it is not known to have taken place.

In the course of my investigations on the rat I have found two cases which are seemingly due to superfœtation. Female $4A_{29}$ had a litter of four young born on December 20, 1910. The male was removed when the litter was discovered and the nest was left undisturbed for fourteen days, when the litter was examined for the sex ratio. At this time the four rats born on December 20 were well developed, and they weighed from 15.5 gm. to 16.4 gm. each. In addition to these rats the nest was found to contain seven very small rats that had apparently been born only a

short time before as they were bright red in color and weighed less than 5 gm. each. Between the birth of the first four members of the litter and of the last seven there was an interval of about fourteen days.

Female $6A\frac{2}{63}$ gave birth to her first litter of three young on February 26, 1912. Thirteen days later the nest was examined and found to contain seven newborn rats that weighed from 4 gm. to 4.5 gm. each. The older members of the litter weighed at this time 10.1 gm., 10.2 gm. and 10.5 gm. respectively. The interval between the birth of the first and of the last members of the litter was in this instance about twelve days. In each of these cases the female with her young occupied an entire cage, so there was no possibility that the newborn rats could have belonged to another female. None of the small rats in these litters were runts, and, with the exception of one that was killed for a museum specimen, all of them were raised to maturity and some were used for breeding purposes.

Female $4A_{29}$ was not examined after her death for any possible malformation of the genital organs. A careful autopsy was made of female $6A\frac{2}{63}$, however, and there was no evidence whatever of any abnormality either in the ovaries or in the uterus. This rat had three other litters besides the one described above, and in each of these litters all of the individuals were born during the one period of parturition.

The cases of superfecundation described in the second section of this paper indicate that a single period of ovulation may extend over three or four days, but it is difficult to see how embryos, born at intervals of two weeks, could possibly have developed from ova belonging to the same period of ovulation. To assume that some of the ova liberated at a given period of ovulation were fertilized at once while others remained in the tubes or in the uterus for nearly two weeks before they were fertilized seems unwarranted; for while it is not known how long mature ova can live without fertilization, it is improbable that they can live for more than a few days at most. That part of the ova belonging to a certain period of ovulation should produce embryos that would be born after a normal gestation period of about 21 days while the rest of the ova had their development so delayed that

they were born only after a gestation period of about 35 days also seems highly improbable. The most plausible explanation for these cases seems to me to assume that the two ovaries acted independently, ovulation occurring in one ovary some little time before it took place in the other. If copulation followed each ovulation two sets of embryos would develop in the uterus simultaneously, and they would be born at different times, depending on the interval between the two periods of ovulation.

Conditions which retard ovulation from one ovary for a greater or a less period of time and so make superfœtation possible must occur very rarely in the rat, since the two cases described are the only ones that have been found in the course of my experiments.

Summary.

1. The normal period of gestation in non-lactating albino rats ranges from 21 to 23 days.

2. The gestation period in lactating albino rats is of normal length if the female is suckling five or less young and is carrying five or less young.

3. The gestation period may be prolonged from one to six days if an albino female, suckling five or less young, is carrying six or more young.

4. The period of gestation is always prolonged when a female is suckling six or more young. In these cases the number of young in the second litter seems to have less influence on the length of the gestation period than has the number of young suckled; but if both litters are very large the gestation period may be extended to 34 days.

5. In the albino rat ovulation takes place within a few hours after parturition.

6. Lactation does not delay ovulation, but the suckling of a litter that contains six or more young seems to lessen the food supply to the fœtal young and so retards their development.

7. Superfecundation occurs occasionally in the albino rat and causes an interval of two or three days between the birth of different members of the litter.

8. In rare instances ovulation takes place in the albino rat during pregnancy and superfœtation occurs. In two cases of

this kind litters have been produced at intervals of about two weeks.

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A CHROMATOID BODY SIMULATING AN ACCESSORY CHROMOSOME IN PENTATOMA.

EDMUND B. WILSON.

A brief account will here be given of a body that first attracted my attention in the spermatogenesis of *Pentatoma* (*Rhytodolomia*) *senilis* Say, where it offers so deceptive a resemblance to an accessory or unpaired *X*-chromosome that it might readily lead to erroneous conclusions could not its entire history be followed out in every detail. A body that is evidently of the same nature but somewhat smaller was afterwards found in *Pentatoma* (*Chlorochroa*) *juniperina* L., and in *Podisus crocatus* Uhler, where it is still smaller. A similar body is often seen also in *Cænus delius* Say, but appears here to be of less constant occurrence. Its behavior is essentially the same in all these cases, and I suspect that it will be found in many other insects. It is probably of the same general nature as the bodies that have been described by various observers as "chromatoid Nebenkörper," "chromatoid corpuscles," etc., in the spermatogenesis of vertebrates, insects, and other animals. In *Pentatoma senilis* it is of very large size, invariably present, and almost always single, though one or two similar but smaller granules often appear also in the same cell. Its constancy and conspicuous character in this species exclude the possibility of error in its identification at any period save the earliest.

As seen during the growth-period and the spermatocyte-divisions it is of rounded form, dense and homogeneous consistency, and after double staining with hæmatoxylin or safranin and light green is at every stage colored intensely blue-black or brilliant red, precisely like the chromosomes of the division-period or the chromosome-nucleoli of the growth-period. In the first spermatocyte-division it may lie anywhere in the cell, sometimes almost at the periphery, but is often close beside the chromosomes. In the latter case it usually lies in, on or near the spindle, lags behind the chromosomes during the anaphases,

and in later stages is found near one pole, presenting an appearance remarkably like that of an accessory chromosome (Figs. 8–10). For such in fact I at first mistook it, even after the discovery that a similar body is often also seen near one pole in the *second* division (Figs. 22, 23); for I supposed this might be a case like that of *Ascaris megalocephala*, where, according to Edwards ('10) the *X*-chromosome may pass undivided to one pole in either the first or the second division. The resemblance is indeed most deceptive; and these division-figures have often been exhibited to other observers as "a remarkably clear demonstration of an accessory chromosome" without at first arousing the least suspicion of the hoax.

The body in question is nevertheless neither an accessory nor any other kind of chromosome; though this did not become wholly certain until after a study of the entire spermatogenesis. It is in fact of protoplasmic origin, first appearing early in the growth-period outside the nucleus, whence it may be followed uninterruptedly through all the succeeding stages until it is finally cast out of the spermatozoön. Upon dissolution of the nuclear membrane it is left lying near the chromosomes, passes without division into one of the daughter-cells in each of the spermatocyte-divisions, and thus enters but one fourth of the spermatids. In the latter it persists with little or no change until a very late stage, sooner or later wanders far out into the sperm-tail, and is at last cast off altogether. It therefore takes no visible part in the formation of the spermatozoön.

I have as yet been able to study the testes of only a single individual of *P. senilis:* but since the whole history of the chromatoid body is clearly shown in this material the facts will be described because of the emphasis that they place on certain possible sources of error in the study of the numerical and sexual relations of the chromosomes. One of the testes was fixed in Flemming's fluid (the best fixation), one in Bouin's, and both were at first stained in iron hæmatoxylin. One of the Flemming slides was also stained in light green: this slide was afterwards extracted and successfully restained with safranin and light green, giving a preparation of great brilliancy. The results given by these four methods of staining are entirely consistent. In all cases

the chromatid body is intensely and purely stained by the "nuclear" dye. In the Flemming material the intranuclear plasmasome, sharply defined and uniformly present, is after hæmatoxylin alone pale yellowish, after both double stains clear green. In the Bouin slides, as is often the case with material thus fixed, the plasmasome stains with hæmatoxylin almost as intensely as the chromosome-nucleolus, and in the earlier part of its history is often indistinguishable from the latter. Unsuccessful attempts were made to restain the Bouin slides with the Biondi-Ehrlich and the Benda (mitochondrial) methods. With the latter, both chromosomes and chromatoid bodies stained alike with the crystal violet after every degree of extraction. With the former method, neither of these bodies could be made to hold the methyl green, both staining alike clear red. I think it probable, however, that with suitable fixation these two kinds of bodies could be differentiated by one or the other method.

I.

Without additional material, including smear-preparations, the interesting history of the chromosomes can not be completely elucidated, owing to certain difficulties in the early and middle prophases. With exception of these stages however the relations of the chromosomes are shown with a diagrammatic clearness that leaves nothing to be desired; and they will be briefly described, both for their own sake and because this is necessary to a complete demonstration of the behavior of the chromatoid body.

The spermatogonial groups (Figs. 1–3) contain six chromosomes, the smallest number thus far recorded in any heteropteran (in *P. juniperina* the number is 14, as in *Euschistus*). Two of these may always be recognized as the largest. Of the remaining four two, as the subsequent history proves, are the *X*- and *Y*-chromosomes; but these differ so slightly in size that they can hardly be distinguished with certainty at this time. The first spermatocyte-division may be described as showing in polar view four chromosomes (Figs. 4–6), including one large (*B*) and one small bivalent (*b*), and the univalent *X*- and *Y*-chromosomes; but the latter lie close together, often in contact, and not seldom

are so closely associated that they might well be reckoned as forming a single tetrad. In the second division *X* and *Y* are uniformly coupled to form a bivalent (Figs. 14, 15); hence but three chromosomes appear in polar view (Fig. 13), and each spermatid receives this number.

The relations of these chromosomes in the spermatocyte-prophases and in the first division show some very interesting features. The autosomes (bivalents) are always characterized by their quadripartite or tetrad structure, being deeply constricted transversely, and also longitudinally cleft, sometimes so markedly that in polar view each appears distinctly double (Figs. 5, 6, 19, 20). This cleft, extremely conspicuous in the prophases, is often less marked during the metaphase, but is again conspicuous in the anaphases, when each daughter-chromosome is always distinctly double, as may be seen with diagrammatic clearness in polar views (Figs. 11, 12). The *X*- and *Y*-chromosomes, on the other hand, are always bipartite and only form a quadripartite body when the two are in contact or closely associated. In the middle prophases they lose their compact, nucleolus-like form and become more or less elongated, looser in texture, and they are now conspicuously split lengthwise, but show no sign of transverse division. In later prophases, as all the chromosomes condense, they shorten more or less but still retain, as a rule, the form of longitudinally split rods at the time they enter the metaphase group. They are at this time frequently in contact end to end (Fig. 17), but *may be quite separate*, though always near together. Their later history is shown in Figs. 18, *a–f*, all of which are accurately represented in the same position with reference to the spindle (in correspondence with Fig. 17). Of this series of figures, *a* and *b* are from metaphases, the others from anaphases. This series, every stage of which is shown in numerous cases in the preparations, clearly demonstrates that the original longitudinally split rods progressively shorten, and that the two halves of each are then drawn apart at right angles to the original long axis. Each chromosome thus assumes a dumbbell shape (*a–c*) and finally divides "transversely"; but it is certain from the earlier stages that this division is only the completion of an original longitudinal split. When *X* and *Y* are closely

associated (as in *a* and *b*) they may be described as forming an actual tetrad, the first division of which is evidently equational.

An excellent opportunity is afforded by these stages for critical comparison of the relative sizes of *X* and *Y*. Such a comparison, made in a large number of cells, shows that a slight but evident inequality almost always exists, the fact being placed beyond doubt by its appearance in both daughter-pairs (Figs. 18, *d–f*). The inequality is however not always seen, perhaps because of slight differences of form or foreshortening. In respect to the size-differences between *X* and *Y*, *Pentatoma senilis* seems to approach *Oncopeltus fasciatus*, as described in my eighth "Study," and differs markedly from *P. juniperina*, where the difference is as evident as in *Euschistus*.

Among numerous cases examined I have not found an exception to the rule that *X* and *Y* lie near together, often more or less in contact, and divide in this position. This relation is maintained during the anaphases, so that in the final stages *X* and *Y* form a pair that is hardly to be distinguished from the small bivalent autosome, now always distinctly double (Figs. 11, 12). Each secondary spermatocyte thus receives three pairs of chromosomes, two of which are the longitudinally divided daughter-autosomes and the third the *XY*-pair. These three double elements enter the second division spindle directly, without forming a "resting-nucleus," and each is separated into its two components (Figs. 14–16). This of course involves the disjunction of *X* and *Y*. In this division the inequality between these chromosomes is almost always in evidence, the appearance of the *XY*-pair being somewhat similar to that of *Nezara hilaris*, as described in my seventh "Study."

It would be hard to find a more convincing demonstration than is here afforded of the relation between univalents and bivalents in the maturation-divisions (*cf.* Wilson, '12) or of the fact that the bivalent is equivalent to two univalent dyads united together. Were the association of *X* and *Y* only a little closer they would in fact form an actual tetrad essentially like the autosome tetrads. Considering the *XY*-pair as such, it evidently divides longitudinally (equationally) in the first division and in the second undergoes a typical reduction-division (disjunction of *X* and *Y*).

Despite the small number of chromosomes I have not been able to understand completely their history during the early and middle prophases, when their elongate form and close apposition to the nuclear membrane renders their complete analysis in sections very difficult. Smear-preparations alone, I believe, will fully clear up the facts. In the middle prophases (Fig. 31) the chromosomes are characterized by the exaggerated character of the longitudinal split (as compared with other insects I have examined) the two halves being often quite as widely separated as in the copepods (Häcker and his followers). Their number at this time often appears to be *five* (instead of the expected number, four), and in some cases even six, the diploid number. This puzzling fact I can not yet fully explain; but it appears to be due to the very wide separation of the two moieties of one or both bivalents at the point where each is destined to undergo "transverse" division in the first spermatocyte-mitosis. It is at any rate certain that this is characteristic of the large bivalent during the earlier period of its condensation, when it often gives the appearance of two separate, longitudinally split chromosomes, separated by a considerable space, and only connected by two delicate strands (Fig. 19, *a*). That this pair represents the large bivalent is fully established by later stages, in which all intermediate conditions connect it with the large bivalent of the metaphase figure (Fig. 19). The same is certainly true in some cases also of the small bivalent (Fig. 20); but I am not sure of the constancy of this. These facts raise the question whether a very late end-to-end conjugation may not take place, in a manner analogous to that described by Gross ('04) at an earlier period in *Syromastes*. The investigation of this point in smear-preparations will probably yield interesting results.

We now return to the history of the chromatoid body. No sign of it is seen in the spermatogonia, nor can it be positively identified in the spermatocytes until some time after the synizesis. But already in the stages immediately following synizesis, as the chromosome-threads are beginning to spread through the nuclear cavity, from one to three very small, deeply staining granules make their appearance in the protoplasm, usually not far from the nucleus, each of which may often be seen to lie in a clear,

vacuole-like space (Fig. 26). In slightly later stages *one* of these granules rapidly enlarges and may soon be distinguished as the chromatoid body (Fig. 27). The other granules seem in many cases to disappear, though they may often be distinguished in addition to the large chromatoid body up to a late stage and even during the divisions (Figs. 29, 30, 10). No evidence can be found that any of these granules are extruded from the nucleus (as has been suggested for the "chromatoid Nebenkörper" by several earlier observers); and it may be pointed out that throughout all these stages both kinds of nucleoli are always clearly visible within the nucleus. Neither can I find evidence of any connection between them and the centrioles, which are first seen in much later stages, lying close against the nuclear membrane.

The chromatoid body reaches its maximum size in Stage *f* or the "confused period" (Fig. 30) when it becomes a most conspicuous element which from this time forward undergoes little or no change until long after its delivery to the spermatids. During this whole period it is always surrounded by a clear, vacuole-like space, and may thus be identified at every stage, even during the divisions. The examination of hundreds of cells during this whole period in *P. senilis* has shown only two or three cases in which more than one such large chromatoid body is present. Its single character seems therefore to be typical of this species. In *P. juniperina*, on the other hand, two such bodies, equal or unequal in size, are more often seen.

From the early post-synaptic stage forwards the nuclei always contain a well defined, conspicuous plasmasome, and one or two intensely stained chromosome-nucleoli. When single, the chromosome-nucleolus is about twice the size shown when two are present (Figs. 26–30). In the earlier stages these bodies are often more or less irregular in form, or elongated. In later stages they are nearly spheroidal, and appear exactly similar, but for their position, to the extra-nuclear chromatoid body. During the prophases the plasmasome disappears, while, as already stated, the chromosome-nucleoli are converted into chromosomes of looser texture, somewhat elongated, and like the bivalents conspicuously split lengthwise. In the final prophases all the

chromosomes become condensed and stain intensely, while the chromatoid body is unchanged (Figs. 32–34). Upon dissolution of the nuclear membrane the latter is left nearly in its original position, often close beside the chromosomes, but still always distinguishable from them by the surrounding vacuole. In the anaphases it usually lies rather close to the spindle, often directly upon it (Fig. 10), sometimes actually embedded within it (Figs. 8, 9) as may be proved by careful focusing. It may however lie quite outside the spindle, even near the cell-periphery. In any case it passes bodily into one of the secondary spermatocytes. There are of course two classes of the latter, with and without the chromatoid body (Figs. 22–25); in the former class its history in the second division repeats that seen in the first. The result is that it enters but one fourth of the spermatids, where it lies in the protoplasm outside the nucleus, and owing to its undiminished staining capacity long remains the most conspicuous object in the cell.

The structure and history of the spermatids agrees in the main with the descriptions of Henking, Paulmier, Gross and Montgomery for other Hemiptera, and need not be described in detail. Each spermatid contains besides the nucleus a large, spheroidal chondriosome-body or nebenkern, a much smaller pale sphere from which arises the acrosome (Figs. 36, 37) and (after the earlier stages) a rather large, intensely staining centriole lying close against the nuclear membrane, from which the axial filament grows out (Figs. 38–43). The later history of these structures agrees closely with Montgomery's account of *Euschistus* ('11). In the earlier stages the chromatoid body, when present, may lie at any point, more commonly in front of or behind the nucleus. Whatever be its original position it is sooner or later, without exception, carried far out into the outgrowing tail of the sperm-cell. It may often still be seen near the anterior pole of the spermatid, near the acrosome-sphere, after the latter has performed its first migration to the anterior pole (Fig. 39) but may lie near the opposite pole (Fig. 40). When the sphere again moves backwards towards the posterior pole of the nucleus the chromatoid body moves with it (Fig. 41) and is never again seen near the anterior pole. By the time the acrosome-sphere has

again moved forward to its definitive position at the anterior pole of the nucleus the chromatoid body is always in the tail (sometimes much earlier), often at a considerable distance from the head.

As the elongation of the tails proceeds, the chromatoid body is carried still further away from the head, finally reaching a position in the middle tail-region. When the nuclei have become elongate, homogeneous and intensely staining, and the immature spermatozoa are aggregated in parallel bundles, the chromatoid bodies are still conspicuously seen (particularly well in the safranin-green preparations) scattered irregularly within the bundles of sperm-tails. They are at this time still enclosed within the tails, lying in the protoplasm outside the chondriosome-envelope of the axial filament; but their elimination shortly takes place. This process is preceded by a marked accumulation of protoplasm that forms a swelling at one side of the tail within which the chromatoid body lies (Figs. 44, 45); but similar swellings are also seen in the spermatids that contain no chromatoid bodies. That these protoplasmic masses are sloughed off in both cases is certain from the ensuing and final stage, though in my rather scanty material I have never been able to catch the process in the very act. In the succeeding stages numerous protoplasmic balls are found lying between the tails (usually more or less definitely aggregated near the middle tail-region of the bundle) and quite separate from them (Fig. 46). It may now be seen with perfect clearness that the chromatoid bodies have been cast off with the protoplasmic balls; for they are now never within the tails but are still perfectly evident in many of the free protoplasmic balls. Counts of the latter show that the chromatoid body is present in about one fourth of them. It still stains as intensely as ever, and is often quite unchanged, but in many cases has now assumed a crescentic shape, as if the central cavity had broken through to the exterior at one side (Fig. 45).

These facts seems to admit of no other interpretation than that a considerable mass of protoplasm is sloughed off from each spermatid, and that it carries with it the chromatoid body when present. It is certain that the latter does not contribute in any visible way to the formation of the spermatozoön.[1]

At every period of its history the chromatoid body is often homogeneous in appearance; but not infrequently it shows more or less definite indications of a central cavity. Here and there one may be found in which the cavity is clearly evident; and now and then a definite, sharply stained central granule appears within the cavity (Figs. 21, 43). This granule has only been seen in the dividing spermatocytes and in the spermatids. Since centrioles are also seen in these stages they are evidently not derived from the central granule of the chromatoid body.

Apart from its smaller size, the chromatoid body in the three other species mentioned shows the same general history as in *P. senilis*. In *P. juniperina* it is at its maximum size hardly more than half as large as in *P. senilis* (Figs. 34, 35); it is very often accompanied by a much smaller and paler granule lying close beside it (Fig. 35). In *Podisus crocatus* it is somewhat smaller than in *P. juniperina* (Fig. 33), in *Cænus delius* still smaller and might readily be mistaken for an accidental granule. In all these cases its behavior seems to be of the same type, and it is surrounded by a similar vacuole. In the two forms last mentioned, perhaps because of its small size, its position in the divisions is more variable, and it more often lies away from the spindle or near the periphery of the cell.

II.

The nature of the chromatoid body need not here be considered *in extenso*. As before stated, it is probably of the same nature as the "chromatoid Nebenkörper" described by various observers in other animals; but I know of no case where the facts are in all respects identical with those seen in *Pentatoma*. In the rat, for example, the "chromatoid Nebenkörper" as described by v. Lenhossék ('98) is in some respect remarkably like that of *Pentatoma:* but this body (two are often present in the earlier

[1] The elimination of protoplasm from the spermatid is of course a well-known and widespread phenomenon. In the cockroach, as described by Morse ('09) the process appears to be similar to that seen in *Pentatoma*, and here also a deeply staining body is cast off, which Morse identifies as a plasmasome. I think it possible, however, that this too may be a chromatoid body comparable with that of *Pentatoma*. I also think it probable that the bodies that have been described as "degenerating cells" in the late spermatid-cysts by some observers are identical with the protoplasmic balls here described.

stages) is stated to be present in all the secondary spermatocytes and also in all the spermatids, where its maximum size is attained. Duesberg ('08) found it only after the first division and believed "qu'il persiste pendant la mitose et se divise pour son propre compte," though the division was not actually seen. Both observers agreed that it degenerates in the spermatid (*cf.* also Meves, '99). Regaud ('10) again describes it in the rat, but finds that it fragments into small granules during the first division and is afterwards reconstituted to form a single body which passes to one pole in the second division, beyond which stage its history was not traced. Such a process of fragmentation certainly does not take place in *Pentatoma*, nor can there be the least doubt of its absence from the greater number of spermatids.

I suspect that the body described by King ('07) as an "acrosome" in the spermatogenesis of *Bufo* belongs in the same general category, though it is described as having a very different history from that seen in either the insects or the mammals. Lastly, I may point out the probable identity of the chromatoid body in *Pentatoma* with that described by Doncaster ('10) in the gall-fly *Neuroterus*, which likewise passes to one pole in the spermatocyte-division. This observer tentatively suggests a possible connection between this body and sex-determination; but the facts seen in the Hemiptera evidently lend no support to this. In none of these cases is the real nature of this body yet clear. In *Pentatoma* it is obviously not a centrosome, centriole, acrosome or extruded nucleolus. Since no definite idiozome is seen in the spermatocytes I suspected for a time that it might be such a body; but this too seems to be excluded by the conditions described in the mammals, where an idiozome is also present.

The nature of the chromatoid body thus remains problematical, but the facts are worthy of serious attention for another reason. Were the chromosomes very small, numerous, closely crowded, or otherwise unfavorable for exact study, and could not the entire history of the chromatoid body be so clearly traced, even an experienced observer might fall into the most confusing error concerning the relations of the chromosomes. It may seem superfluous to urge the danger of confusing with chromosomes other compact and deeply staining bodies that may lie near or

among them, or at the spindle poles—extruded nucleoli or nucleolar fragments, chromatoid bodies, "acrosomes," yolk-granules, or the like—but one can not avoid the suspicion that some of the existing contradictions in the literature may have arisen from some such source. Many cases might be cited in illustration of the danger of such confusion. I suggest, for instance, a comparison of my Figs. 9, 10, 22, 23 of *Pentatoma* (first and second division) with Stevens's Fig. 5 of the first division of *Ceuthophilus* ('12), the same author's Fig. 71 of *Stenopelmatus* ('05), Morse's Fig. 46 of *Periplaneta* ('09), and Duesberg's Fig. 45 of the rat ('08). In all of these cases a compact, more or less deeply stained, spheroidal body is seen near one pole in the telophases or late anaphases, lying near the chromosome-group; and the similarity is increased by the fact that in the first three of these cases this body is surrounded by a clear, vacuole-like space. So deceptive is this resemblance that any observer without careful study might readily conclude that the body in question is in each case an accessory chromosome; yet in only two of the five cases would this conclusion be correct. In *Pentatoma* and the rat this body is of protoplasmic origin (chromatoid body), in *Periplaneta*, according to Morse, an extruded nucleolus (plasmasome). Only in *Ceuthophilus* and *Stenopelmatus*, if Miss Stevens's conclusions were correct (I have no reason to doubt that they were) is this body an accessory chromosome.

Such facts make it clear that the presence of sex-chromosomes can not safely be inferred alone from the presence of chromosome-like bodies lagging on the spermatocyte-spindles, or lying near one pole. The presence of compact, deeply staining nucleoli during the growth-period is by itself equally indecisive. In some cases the "plasmasome," especially after certain fixatives such as Bouin's fluid, may stain quite as intensely as the chromosome-nucleoli with hæmatoxylin, safranin and other dyes (*cf.* Gutherz, '12). Decisive evidence regarding these bodies can only be obtained by tracing their individual history and by accurate correlation of the chromosome-numbers in the spermatogonial and spermatocyte-divisions. It hardly need be added that great caution is necessary in dealing with difficult material in which for any reason such a test can not be completely carried out.

COLUMBIA UNIVERSITY, February 19, 1913.

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Explanation of Plates.

Plate I.[1]

(*Pentatoma senilis.*)

Figs. 1–3. Spermatogonial metaphase-groups; 4–6, first spermatocyte-division in polar view; 7, early anaphase, the large bivalent also shown separately at the left; 8–10, late anaphases; 11, 12 the same in polar view, sister-groups from the same spindle (the identification of *X* and *Y* not entirely certain); 13, second spermatocyte metaphase-group, with chromatoid body; 14–15, the same in side view, chromatoid body absent; 16, the same, with chromatoid body near one pole.

[1] All the figures from camera drawings, enlarged about 2,500 diameters. *A* designates the acrosome, *B* the large bivalent, *b* the small bivalent (or their products), *C* the chromatoid body, *N* the Nebenkern or chondriosome-body, *X* and *Y* the sex-chromosomes.

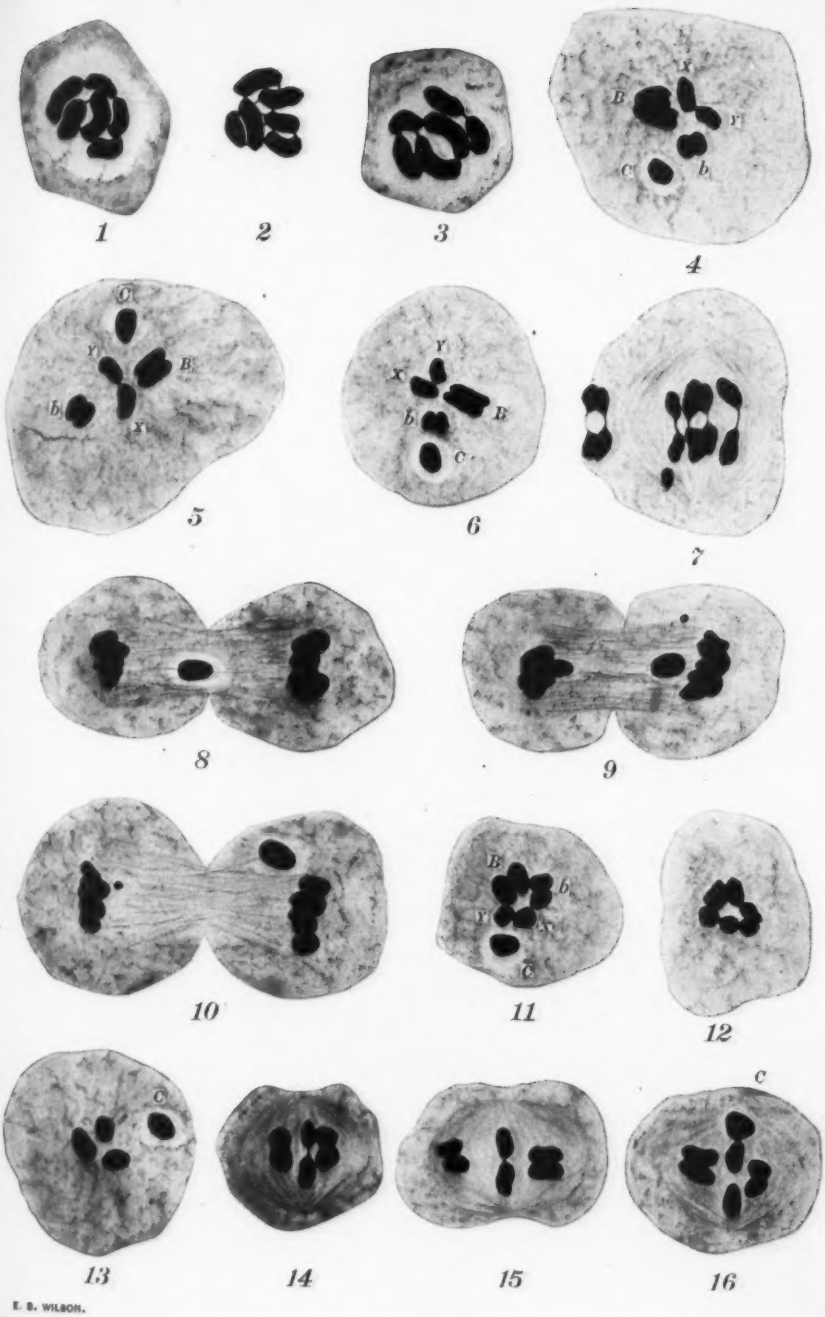

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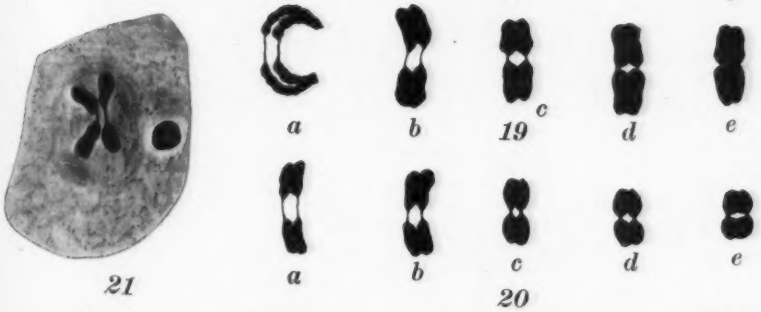
PLATE II.

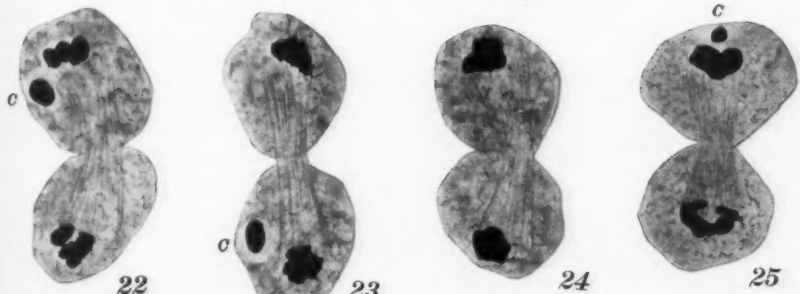
(*Pentatoma senilis*, except 25.)

FIG. 17. First spermatocyte-metaphase chromosomes from a single spindle, with chromatoid body, artificially spread out in a series for comparison, the large bivalent seen sidewise; 18, *a–f*, the *XY*-pair in successive stages, all in the same position with reference to the spindle (as in Fig. 17), *a* and *b* from metaphases, *c–f* from anaphases; 19, *a–e*, the large bivalent in successive stages, *a–d* from prophase-nuclei, *e* from metaphase; 20, *a–e*, corresponding series of small bivalent, *a–c* from prophase-nuclei, *d*, *e*, from metaphases; 21, tangential section of first division showing *XY*-pair and chromatoid body; 22, 23, second spermatocyte-telophases, with chromatoid body; 24, the same without chromatoid body; 25, the same with chromatoid body near one pole, *Pentatoma juniperina;* 26–29, early growth-period; 30, confused period; 31, middle prophase; 32, late prophase, all the chromosomes foreshortened.

17 18



19 20 21



22 23 24 25

26 27 28 29

30 31 32

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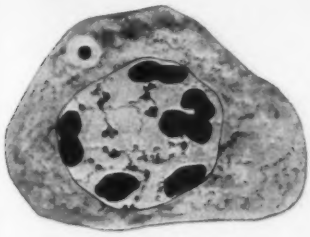
PLATE III.

(*Podisus crocatus*, 33; *Pentatoma juniperina*, 34, 35; *P. senilis*, 36–46.)

FIG. 33. Late prophase, *Podisus crocatus*; 34, the same, *Pentatoma juniperina*; 35, first spermatocyte-anaphase of the same species; 36–43, stages in the development of the spermatids, *P. senilis*; the large dark body is the chromatoid body; 44, 45, central region of the tail, later spermatids, showing protoplasmic swelling enclosing chromatoid body; 46, group of cast-off protoplasmic balls lying between the sperm-tails, four containing chromatoid bodies, young spermatozoa.



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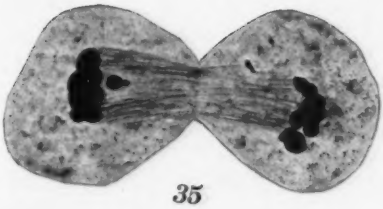

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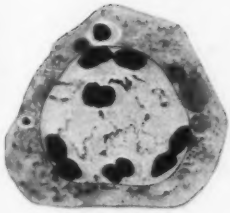

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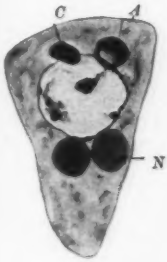

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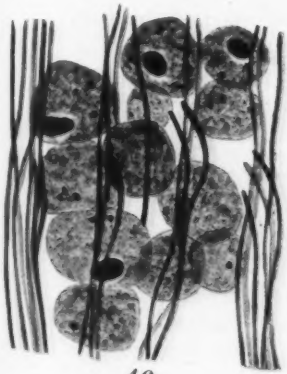

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REACTIONS OF AMŒBA PROTEUS TO FOOD.

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In material taken from a pond southwest of the university we found great numbers of *Amœba proteus*. These animals appeared in a brown scum at the surface of the aquarium. The *Amœba* is one of the simplest animals and hence is an attractive form in which to study the phenomena of life. The simplest vital phenomenon—movement—is of course involved in the food reactions of *Amœba*. Rhumbler and others once held that the movement of *Amœba* could be explained by means of variation of surface tension upon the body of the animal. Jennings was the first to attack this theory. He demonstrated the currents of the protoplasm on the surface of *Amœba* by causing soot to adhere to the surface of the animal. These experiments showed that surface tension could not explain these currents and therefore could not explain the movement of *Amœba*. Later Dellinger ('06) likewise showed that surface tension could not explain this movement, for he saw that in advancing an *Amœba* threw out a pseudopodium, the end of which it fixed by adhesion to the substratum and then through the contraction of this fixed pseudopodium the body was dragged to the point of attachment to the substratum. Rhumbler ('05) according to his reviewer in answer to Jennings' criticism pointed out that in his work "it (Rhumbler's surface tension theory of movement) is not dependent on the movements termed 'Föntanen-strömung,' whose existence Jennings calls in question. These movements, though not frequent, certainly do occur in some *Amœbæ:* it is not their unconditional necessity, but their theoretical value as a starting point, which accounts for their occupying the chief place in the author's theories. It is not claimed that there is more than a parallel value or 'convergence' shown in the comparative experiments with organic and inorganic mechanics; the chemistry in both is fundamentally different. It is possible that in

the *Amœba* resides a 'Miniaturpsyche'—an energy absent in the inorganic." Thus the simplest phenomenon of life in one of the simplest animals has not been reduced to terms of physics and chemistry.

Despite this fact there is much, as yet, said concerning the physical and chemical explanation of the food-reactions of *Amœba*. For instance Hegner ('10) says in speaking of the food reaction of *Amœba* that "this apparent choice of food may be due to ordinary physical laws of fluids." Likewise Calkins ('09) says: "While most of the actions of protozoa are reactions to external stimuli, many are combinations of reactions which do not lend themselves to analysis. Such, for example, is the apparent choice of food or of building material for shells and tests, or the complex reactions that are frequently involved in the avoidance of some obstruction. Many of these so-called conscious acts can be explained by the ordinary physical laws of fluids."

At a more recent date McClendon ('12) showed that by a disturbance of the electrical polarization the surface tension would be modified and adds: "We might conclude therefore that the low surface tension of the *Amœba* is caused by electric polarization, due to the production of some metabolic electrolyte whose anions cannot escape; and that strong stimulation causes increased permeability and hence disappearance of the electrical polarization.

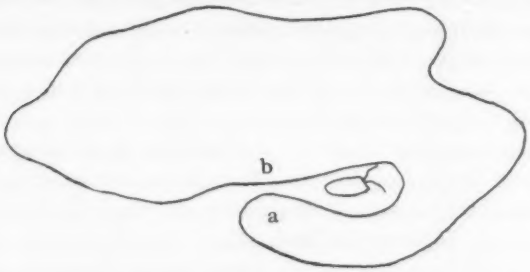
"This would explain all negative tropisms of the *Amœba*. The surface tension of the portion most strongly stimulated is increased, and the *Amœba* flows away from the stimulus.

"In order to explain positive tropisms we would have to make another assumption. If the stimulus did not react directly on the plasma membrane, but penetrated the *Amœba* and acted on the protoplasm, and increased the production of the metabolic product producing polarization of the plasma membrane, it would thereby decrease the surface tension. The local decrease in surface tension would cause the *Amœba* to flow toward the source of the stimulus, just as the quicksilver drop in dilute HNO_3 flows toward potassium bichromate in Bernstein's experiment."

The food-reaction of *Amœba* involves movement. It is however, a more complex phenomenon than mere movement. "The capture and ingestion of food, in its simplest form, occurs in the group of Rhizopoda, where, as in *Amœba proteus*, any part of the body can act as a mouth. In this form pseudopodia are pushed out toward the victim (a flagellate, ciliate, minute plant form of any kind, or even a higher animal, such as a rotifer or worm) and entirely surround it, together with a certain amount of water, thus forming a gastric vacuole, or an improvised 'stomach'" (Calkins '01). This description gives the details as generally given for the ingestion of food.

So far as we have been able to determine no departure from this simple method of capturing food by an *Amœba proteus* has been described. Jennings observed an *Amœba* persistently push a spheroidal *Euglena* cyst from place to place in an effort to ingest it. He also observed an *Amœba proteus* ingest repeatedly a smaller specimen of *Amœba proteus*, the latter each time breaking through the protoplasmic wall of its captor. But even in these most interesting instances the prey was taken into the body by the ingesting protoplasm flowing about each side of the prey with equal velocity. On September 25, Mr. F. L. Kline, Mr. W. A. Williams, Mr. J. P. Williams and Mr. R. T. Scott called the attention of one of us to an *Amœba proteus* that was sending a pseudopodium out from the side of its body posteriorly in such a way as to surround a quiet *Chilomonas paramœcium*. In this case it was remarkable that the entrapping protoplasm was flowing about but one side of the prey, the side of the *Amœba's* body furnishing one wall of the forming food vacuole. Later Mr. Scott observed that the food vacuole was completed through the fusion of the end of the pseudopodium and the side of the body (text-figure 1). September 26, Mr. E. M. Baker called our attention to an *Amœba proteus* that had a *Chilomonas paramœcium* lying between two pseudopodia as indicated in Fig. 1, *a*. He had not observed where the contact with the prey had been made, but it was evident that the two pseudopodia were closing up behind the *Chilomonas paramœcium*. We then called the attention of Mr. C. A. Amos, Mr. H. H. Buehler, and Mr. A. H. Brewster to the specimen. As we took turns with these

men in observing it the left pseudopodium alone grew. As it elongated it travelled along the inner side of the right pseudopodium to its base. At the base of the right pseudopodium the growing left one turned along the surface of the body and then travelled "anteriorly" until the prey was entwined by it. When thus the enclosing space had been greatly reduced the left pseudo-



TEXT-FIGURE 1. Outline of an *Amœba proteus*, showing the manner in which the pseudopodium *a* developed along the outer side of a *Chilomonas*. Eventually the apex of the developing pseudopodium, *a*, fused with the body at *b*. In this manner the *Chilomonas* was taken into the body of the *Amœba*. (The position of the axis of the *Chilomonas* was not observed. The point of contact of the *Chilomonas* with the surface of the *Amœba* was likewise not noted.)

podium fused along its two margins at the place indicated in Fig. 1, *e* by a broken line.

These observations led us to make further studies on the food reactions of *Amœba proteus*. An *Amœba proteus* with two pseudopodia projecting and flowing for the most part into the larger one came in contact with a quiet *Chilomonas paramœcium* (Fig. 2). The *Chilomonas paramœcium*, thus disturbed, retreated to the position indicated by the finely stippled outline (Fig. 2). Again the pseudopodium came in contact with the *Chilomonas* and the latter then retreated to the position indicated by the darkest contour. As the *Chilomonas* lay in this position the *Amœba proteus* approached it and this time without disturbing the flagellate sent protoplasmic processes about its sides until the prey was enclosed within a food vacuole. This observation does not depart greatly from what has been generally described as the usual reaction of *Amœba proteus* to food.

The next observation, however, is quite unusual. The *Chilomonas paramœcium* in this case ran into the side of an *Amœba proteus* that was "flowing into" a curved pseudopodium. In this case the large pseudopodium flowed back along the outer side of the *Chilomonas* until the tips of the two pseudopodia fused (Fig. 3).

We have seen three instances of a *Chilomonas paramœcium* and one instance of a diatom entering the *narrow* angle between two pseudopodia and coming in contact with the ectoplasm at the apex of this angle. In all these cases the reactions were analogous. The specimen represented in Fig. 4 had a *Chilomonas paramœcium* swim into the narrow angle between two pseudopodia and which made repeated contacts at *a*. The response to this stimulus at *a* resulted in the formation of pseudopodia behind the *Chilomonas* at *b* and *c*.

In contrast with the last observations is one made upon a specimen that had two *widely* diverging pseudopodia. The general movement of the body was in the larger pseudopodium. A *Chilomonas paramœcium* came in contact with the middle of the mesial surface of the smaller pseudopodium. The flagellate made a single impact at this point and lay in contact with the ectoplasm. In response to this contact the *Amœba proteus* sent out a third protoplasmic process from the apex of the angle between the first two pseudopodia (Fig. 5, *a*), thus placing the object of prey in a narrow angle between two pseudopodia. Before the end of pseudopodium *a* reached the level of the end of its neighbor it changed its course so as to flow behind the *Chilomonas*. At the same time the original pseudopodium sent out a secondary one (Fig. 5, *b*) below its apex to meet the other enclosing pseudopodium. In this way the *Chilomonas* was enclosed in a food vacuole of about the usual size.

Other conditions may arise with reference to the capturing of the *Chilomonas paramœcium* by the *Amœba proteus*. *Chilomonas* sometimes seems quite indifferent to the contact of the *Amœba proteus*. On September 30, a specimen of the latter was observed which came in contact with a flagellate at the apex of its more active pseudopodium (Fig. 6, *a*, 1.) As the pseudopodium grew the *Chilomonas* glided along its surface to the

position 2 in Fig. 6, *a*. When the flagellate was left a little farther beyond the apex of the growing pseudopodium the streaming movement of the latter changed its course so as to cause the pseudopodium to send a process or secondary pseudopodium off behind the quiet *Chilomonas*. This process or secondary pseudopodium, through a streaming at right angles to the larger one, grew somewhat larger, then its course became oblique and it traveled like a wave posteriorly along the mesial surface of its parent pseudopodium. This wave-like movement of the secondary pseudopodium carried the yet quiet *Chilomonas* down to the apex of the angle between the two original pseudopodia. Thus the prey was brought into a relatively small space, which through the fusion of the tip of the secondary pseudopodium and a region near the base of one of the original pseudopodia, became a food vacuole (Fig. 6, *a*, *b*, *c* and *d*).

Perhaps the most interesting condition we have seen presented to the ingenuity of the *Amœba proteus* is to be seen in the following observation. The *Amœba proteus* was traveling along the line of a large pseudopodium when it came in contact with a quiet *Chilomonas paramœcium*. At first the *Amœba proteus* seemingly did not react but simply pushed the *Chilomonas* to one side (Fig. 7, 2). At this point, however, the *Amœba proteus* protruded a small pseudopodium from the apex of the larger one which proceeded around the *Chilomonas* (Fig. 7, *a*). At the same time it threw out a secondary pseudopodium from the body of the larger one some distance below the *Chilomonas* (Fig. 7, *b*). It, however, withdrew this secondary pseudopodium at *b* and threw out another one (Fig. 7, *c*), closer to the *Chilomonas* which immediately proceeded to meet the first enclosing pseudopodium, *a*.

After the extreme variability of the *Amœba's* reactions to food as seen in these observations one is not justified in saying as does Hegner ('10), "This apparent choice of food may be due to the ordinary physical laws of fluids." In the first place as many if not more *Chilomonas paramœcia* were rejected as were accepted by the *Amœbas*. Frequently a *Chilomonas paramœcium* would come in contact with the "anterior end" or side and then remain by the *Amœba* without being ingested. If this were a process involving the "ordinary physical laws of fluids" there would

be no rejection of food when it presented itself in a manner favorable for acceptance. Nor does it follow that when an *Amœba* has rejected food that this rejection is final. On September 26, Mr. L. Grady Burton saw an *Amœba proteus* which was flowing along the line of a large pseudopodium come in contact with a quiet *Chilomonas paramœcium*. The *Amœba proteus* twice touched the *Chilomonas* and each time withdrew its pseudopodium. The *Amœba proteus* then moved around and by the *Chilomonas*. It now lay opposite a side which was at right angles to the one first encountered. The *Amœba* then sent out a pseudopodium at right angles to the first one and again touched the *Chilomonas*. It rejected the flagellate again but on touching it the second time in this new position the *Amœba proteus* ingested the *Chilomonas*.

These reactions too show a departure from the description given by Jennings ('06). "The essential features of the food reaction seem to be the movement of the *Amœba* toward the food body (long continued, in some cases), the hollowing out of the anterior end of the *Amœba*, the sending forth of pseudopodia on each side of and above the food, and the fusion of the free ends of the pseudopodia thus enclosing the food, with a quantity of water. The reaction is thus complex; at times, as we have seen, extremely so."

As we have been able to observe the reactions of the *Amœba proteus* are not always "the hollowing out of the anterior end of the *Amœba*, the sending forth of pseudopodia on each side of and above the food, and the fusion of the free ends of the pseudopodia"; but the reaction is a variable one and may arise from the side of the *Amœba's* body and involve primarily but a single pseudopodium.

Moreover the reaction of an *Amœba proteus* to food is in each case determined by the conditions presented at the time of contact. Some of these conditions are:

1. The metabolic condition of the *Amœba proteus*, demanding or not demanding food.

2. The form of the *Amœba's* body at the time the food is presented to it with reference to (*a*) the amount of water that may enter a food vacuole, and (*b*) the possible retreat of the object of prey.

So far as our observations are concerned little can be said about the first condition. The relative number of food vacuoles did not seem to make any marked difference in the conduct of the *Amœba* with reference to food. It was not in our power in any way to determine whether the metabolic conditions of the *Amœba* demanded food or not.

Our observations are chiefly concerned with the manner in which the *Amœba* met the conditions of not getting too great an amount of water into the food vacuole and of not letting the prey escape. We can readily understand how by dilution of ferments a relatively large quantity of water in a food vacuole might present a condition to the *Amœba* in taking in food. The amount of water, therefore, that may enter a food vacuole is one of the dominate factors in controlling the way in which an *Amœba* reacts to the prey.

This condition we infer was the primary one determining the action of the *Amœba* represented in Fig. 1. Here the object of prey when first seen lay out away from the surface in a wide angle between two pseudopodia. The stimulus of its contact (not observed by any of us) resulted in the pseudopodia bending their tips towards each other. Had these tips fused the basis of a very large food vacuole would have been formed. No fusion took place here. In the manner described above the one pseudopodium was wrapped about the *Chilomonas* until a relatively small space was enclosed over which an ectoplasmic film arched leaving only a small bilobed aperture (Fig. 1, *e*, *ap*). Out of this small bilobed aperture water was apparently forced, for the enclosure became gradually smaller and after it was reduced to the size of the food vacuole usually encountered the bilobed opening was closed through the convergence and fusion of its lips. After this pore was closed the endoderm also came to lie over the upper side of the food vacuole. In this rather remarkable manner the prey was not allowed to escape and a food vacuole with a relatively small amount of water was formed.

The reaction of the *Amœba* represented in Fig. 2 is like that usually described for the conduct of an *Amœba* with reference to food. Here the amount of water that is to enter the food vacuole is not so great a conditioning factor but the reaction is rather

conditioned by the great chances afforded for the escape of the prey. So after disturbing the prey twice and causing it to retreat as often along the projected axis of the pseudopodium the *Amœba* did not disturb the prey but sent about it pseudopodia which eventually enclosed the quiet *Chilomonas*. This is of further interest in demonstrating that the reaction of *Amœba* to food is not a fixed one for twice the *Chilomonas* was rejected and the third time deliberately accepted.

In contrast with this reaction is that of the *Amœba* shown in Fig. 3. Here a *Chilomonas*, after making contact with the ectoplasm of the *Amœba*, lay in between two pseudopodia, one of which presented an inwardly directed surface and the other an outwardly directed surface. If the disturbed prey were to strike the former it would be deflected towards the fundus of the interpseudopodial space, whereas if the disturbed prey were to strike the latter it would be deflected away from the space which is to form the basis of a food vacuole. Thus in this case the possible retreat of the prey may be the chief condition to be met.

When an object of prey entered a narrow angle between two pseudopodia the possible retreat of the prey again became the principal conditioning factor. If the *Amœba* had reacted at the point of contact by sending out secondary pseudopodia towards each side of the prey it would have crowded back the prey and thus result in its escape. To prevent this escape the *Amœba* sent secondary pseudopodia behind the *Chilomonas paramœcium* as described for Fig. 4 on page 415.

Further it is interesting to note that in this case the stimulus was encountered at *a* and the reaction took place at *b* and *c* (Fig. 4). Thus we see that here it is not as Jennings ('06) says in reference to locomotion that "it is primarily the part stimulated that responds." For in this reaction it was not the part immediately stimulated but the parts that could most advantageously respond that did so.

Where it was more advantageous for another part or parts to respond we find that they responded. Take for example the case in which the object of prey entered a broad angle between two pseudopodia as described on page 415 for Fig. 5. If the *Amœba* had reacted in the manner just described it would have

been easier for the prey to escape and the food vacuole would have contained a large quantity of water. For these and probably other unknown reasons the *Amœba* reacted by sending out a secondary pseudopodium which placed the prey in a narrow angle and then ingestion took place practically the same way as described above for the reaction to food in a narrow angle (Fig. 5).

Before leaving observations 4 and 5 a useful comparison should be made. In the reaction of the *Amœba* represented in Fig. 4 the suggestion might be raised that pseudopodia grew with equal velocity at *b* and *c* because of more or less equal stimuli caused by vortices in the wake of the prey. But in answer to this suggestion we have the reaction of the *Amœba* in Fig. 5. Here we see the contact was made obliquely to the surface and that the larger pseudopodium arose at a point most remote from the path of the prey. *So the reaction was greatest where the stimulus was weakest but where the conditions demanded greatest reaction.*

When the *Chilomonas paramœcium* in Fig. 6 was left in position 2 it lay at a point on the surface which would not direct its possible movements towards the fundus of the space between the two pseudopodia. So, as if in order to prevent its direct retreat from this space, a secondary pseudopodium grew up behind the prey. The manner in which the secondary pseudopodium travelled as a wave along the mesial surface towards the fundus of the interpseudopodial space met the conditions determined by the possible escape of the prey and the usual or maximum size of a food vacuole.

The second relatively large pseudopodium in this case seems to have been a determining structure in this reaction. The position of the *Chilomonas* too may have been a factor in it, for in these two respects the *Amœbas* shown in Figs. 6 and 7 differ. In the latter there is no second pseudopodium to coöperate with the first and the axis of the body of the *Chilomonas* shown in Fig. 6 lies more or less parallel to the surface of the pseudopodium whereas in the *Amœba* shown in Fig. 7 the *Chilomonas* in position 2 lies at right angles to the surface of the pseudopodium. Thus the *Chilomonas* in the latter instance has all paths for retreat open except that towards the surface of the pseudo-

podium. Hence the possibility of escape of the prey again becomes the conditioning factor in the reaction, which is met in the manner described on page 416.

In the *Amœba* which presented the reaction shown in Fig. 7 we again see that it is not the part stimulated that primarily reacts nor is the response for a given stimulus a fixed one. The stimulus in this case was made at the point *d* and at first the tip of the pseudopodium *a* grew along the far side of the prey while a smaller pseudopodium arose at *b*. Later this first reaction was greatly modified to better meet the involved conditions. This modification was accomplished through a negative response at *b* and a positive response at *c*. This reaction, so modified, was a better one in so far that it made the escape of the *Chilomonas* less probable. Thus we have an example of the *Amœba proteus* attaining its end through trial and error since the reaction to a given stimulus was modified with reference to more readily realizing the object of the reaction.

Conclusions.

1. The reactions of *Amœba proteus* are highly variable in reference to: (*a*) power of accepting or rejecting food; (*b*) method of ingesting food.

2. In all this variability of reaction there appears no haphazardness. The reactions are not automatic responses. Each reaction is a response made to suit the peculiar conditions presented at the moment of accepting or rejecting the food; and if not well suited to meet these conditions, it is modified with reference to better meeting them. Thus in each reaction there is evidence of purposiveness.

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[1] The same day that the page proof of this article came to the authors Prof. F. J. Wright sent us a reprint of "Daily Life of Amœba Proteus" by David Gibbs, Clark University. No reference has been made to this important paper in our paper. Authors.

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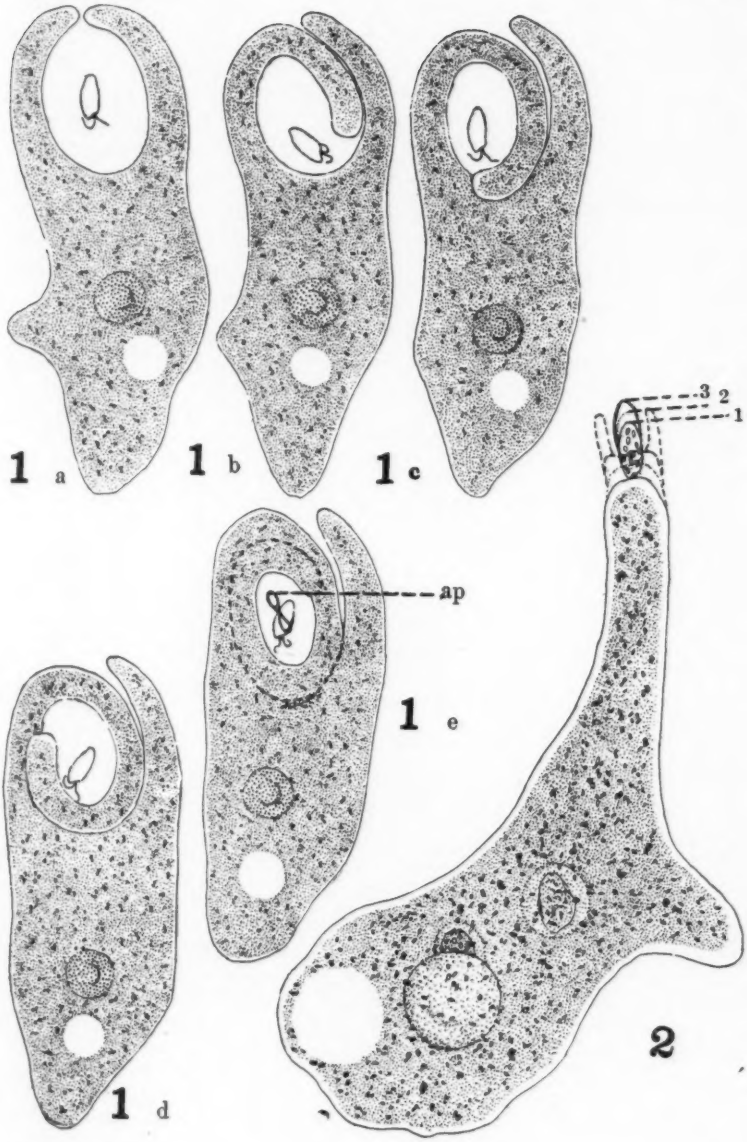
EXPLANATION OF PLATE I.

FIG. 1. (*a*) The pseudopodia have closed behind the prey; (*b*), (*c*), (*d*), and (*e*) shows how the left pseudopodium grew down along and then away from the right pseudopodium. The broken line in (*e*) indicates the place where the two surfaces of the left pseudopodium fused to enclose the prey. (*ap*) indicates the bilobed margin of the ectoplasm that over-arched the forming food vacuole. ×166.

FIG. 2. The *Chilomonas paramæcium* was first encountered at position 1. The prey next retreated to position 2, indicated by the dotted contour. When the second contact with the *Amœba proteus* was made it retreated to position 3. The contour of the position 3 is indicated by the darkest line. It lay in this third position when it was ingested by the *Amœba*. ×333.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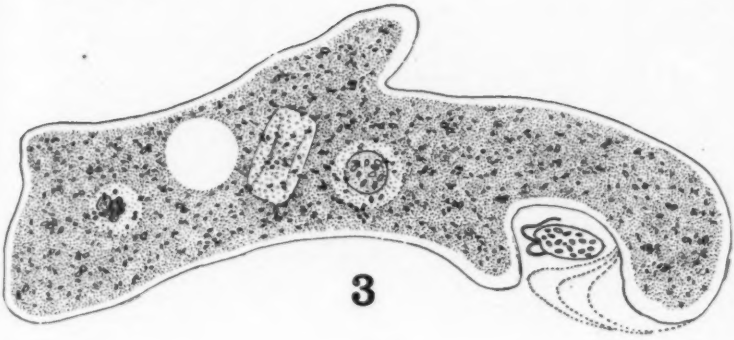
EXPLANATION OF PLATE II.

FIG. 3. Shows a *Chilomonas* lying between a lateral and a terminal pseudopodium. The response to the contact or contacts made by the *Chilomonas* was the lateral and posterior growth of only the terminal pseudopodium. The successive steps in the advance of this pseudopodium is indicated by the broken lines. ×333.

FIG. 4. The *Chilomonas* by advancing and retreating made three contacts at *a*. The response of the *Amœba* to these contacts was not at the point stimulated but at points (*b*) and (*c*). From these points secondary pseudopodia grew towards each other and fused behind the prey, as indicated by the dotted lines. ×333.

FIG. 5. A *Chilomonas* entered the wide angle between the two large pseudopodia in the direction indicated by the arrow. When it met the *Amœba* it lay in contact with the ectoplasm. In response to this contact a small secondary pseudopodium (*b*) arose behind the prey and a large pseudopodium (*a*) arose from the apex of the inter-pseudopodial angle. ×333.



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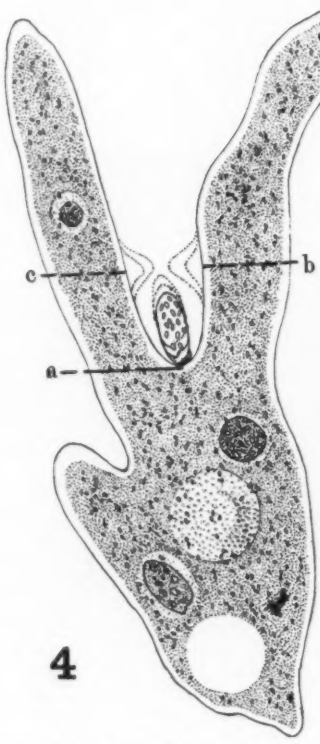

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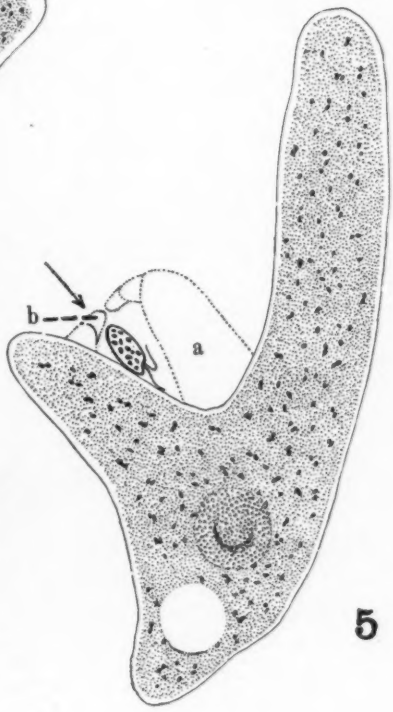

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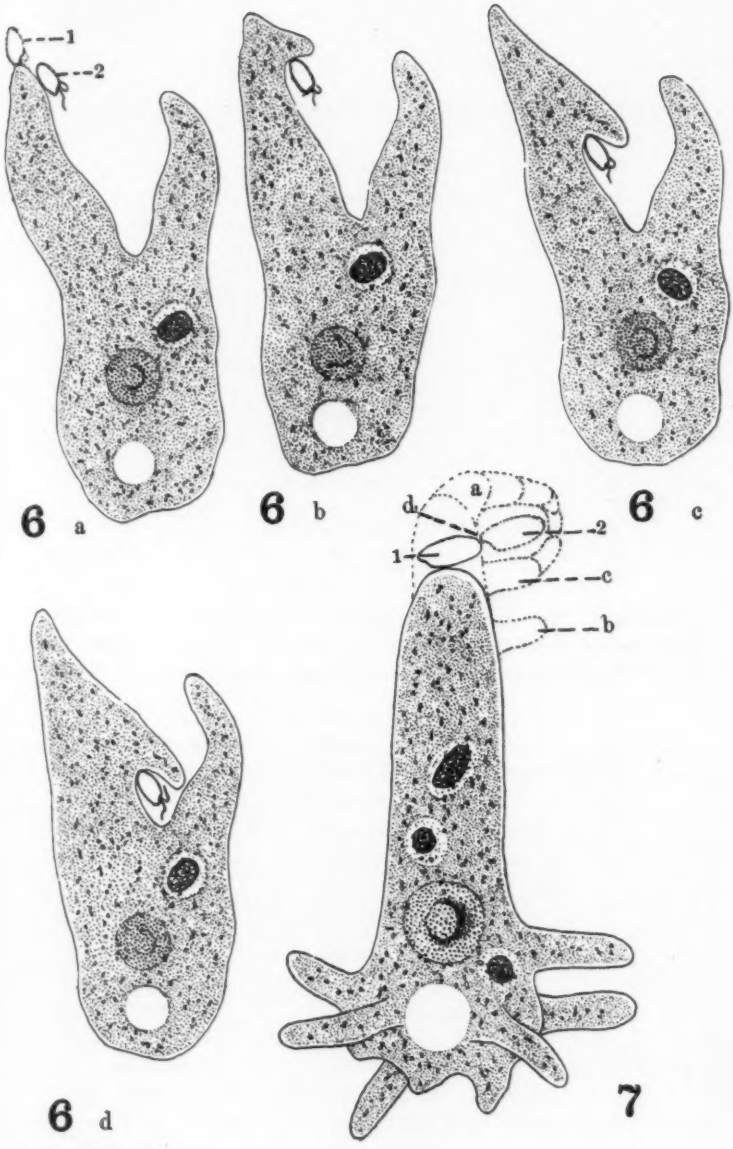
KEPNER AND TALIAFERRO.

Explanation of Plate III.

Fig. 6. (*a*) The *Chilomonas* first lay at the apex of the pseudopodium. As the pseudopodium advanced it glided by the *Chilomonas* so that the latter lay to the right in contact with the ectoplasm at the point indicated by position 2. (*b*), (*c*), and (*d*) show the wave-like character of the reaction. This reaction crowded or dragged the passive prey down into the fundus of the interpseudopodial space where the *Chilomonas* was enclosed in a vacuole formed by the fusion of the apex of the lateral active pseudopodium and the base of the right, inactive pseudopodium. ×166.

Fig. 7. The large pseudopodium of *Amæba* came in contact at its apex with the *Chilomonas* (1). The *Chilomonas* was then pushed to position (2). The pseudopodium next advanced beyond the prey and turned to the right at (*a*) along its upper side. At the same time a secondary pseudopodium was thrown out at (*b*). Later this reaction on the part of the *Amæba* was changed; the pseudopodium at (*b*) was withdrawn and one thrown out at (*c*) to better meet the conditions necessary for the capture of the prey. Pseudopodia (*a*) and (*c*) then grew around the *Chilomonas* and enclosed it in a food vacuole. ×333.



KEPNER AND TALIAFERRO.

THE MARINE BIOLOGICAL LABORATORY

FIFTEENTH REPORT

FOR THE YEAR 1912

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I. TRUSTEES

EX OFFICIO

F. R. LILLIE, *Director*, The University of Chicago.
GILMAN A. DREW, *Assistant Director*, Marine Biological Laboratory.
D. BLAKELY HOAR, *Treasurer*, 161 Devonshire Street, Boston, Mass.
G. N. CALKINS, *Clerk of the Corporation*, Columbia University.

TO SERVE UNTIL 1916

H. H. DONALDSON.....Wistar Institute of Anatomy and Biology.
M. J. GREENMAN.....Wistar Institute of Anatomy and Biology.
C. W. HARGITT.....Syracuse University.
H. S. JENNINGS.....Johns Hopkins University.
GEORGE LEFEVRE.....University of Missouri.
A. P. MATHEWS.....The University of Chicago.
G. H. PARKER.....Harvard University.

TO SERVE UNTIL 1915

H. C. BUMPUS.....University of Wisconsin.
R. A. HARPER.....Columbia University.
W. A. LOCY.....Northwestern University.
JACQUES LOEB.....Rockefeller Institute for Medical Research.
F. P. MALL.....Johns Hopkins University.
GEORGE T. MOORE.....Missouri Botanical Garden, *Secretary of the Board.*

L. L. NUNN.....Telluride, Colo.
JOHN C. PHILLIPS.....299 Berkeley Street, Boston, Mass.

TO SERVE UNTIL 1914

CORNELIA M. CLAPP.....Mount Holyoke College.
E. G. CONKLIN.....Princeton University.
ROSS G. HARRISON.....Yale University.
CAMILLUS G. KIDDER....27 William Street, New York City.
M. M. METCALF.....Oberlin College.
WILLIAM PATTEN.....Dartmouth College.
JAÇOB REIGHARD.....University of Michigan.
W. B. SCOTT.....Princeton University.

TO SERVE UNTIL 1913

S. F. CLARKE.....Williams College.
CHARLES COOLIDGE.....Ames Building, Boston, Mass.
C. R. CRANE.....2559 Michigan Boulevard, Chicago, Ill.,
President of the Board.
ALFRED G. MAYER.....Carnegie Institution.
T. H. MORGAN.....Columbia University.
ERWIN F. SMITH.....United States Department of Agriculture.
E. B. WILSON.....Columbia University.

II. ACT OF INCORPORATION

No. 3170.

COMMONWEALTH OF MASSACHUSETTS

Be It Known, That whereas Alpheus Hyatt, William Sanford Stevens, William T. Sedgwick, Edward G. Gardiner, Susan Minns, Charles Sedgwick Minot, Samuel Wells, William G. Farlow, Anna D. Phillips and B. H. Van Vleck have associated themselves with the intention of forming a Corporation under the name of the Marine Biological Laboratory, for the purpose of establishing and maintaining a laboratory or station for scientific study and investigation, and a school for instruction in biology and natural history, and have complied with the provisions of the statutes of this Commonwealth in such case made and provided, as appears from the certificate of the President, Treasurer, and Trustees of said Corporation, duly approved by the Commissioner of Corporations, and recorded in this office;

Now, therefore, I, HENRY B. PIERCE, Secretary of the Commonwealth of Massachusetts, *do hereby certify* that said A. Hyatt, W. S. Stevens, W. T. Sedgwick, E. G. Gardiner, S. Minns, C. S. Minot, S. Wells, W. G. Farlow, A. D. Phillips, and B. H. Van Vleck, their associates and successors, are legally organized and established as, and are hereby made, an existing Corporation, under the name of the MARINE BIOLOGICAL LABORATORY, with the powers, rights, and privileges, and subject to the limitations, duties, and restrictions, which by law appertain thereto.

Witness my official signature hereunto subscribed, and the seal of the Commonwealth of Massachusetts hereunto affixed, this twentieth day of March, in the year of our LORD ONE THOUSAND, EIGHT HUNDRED and EIGHTY-EIGHT.

HENRY B. PIERCE,
Secretary of the Commonwealth.

[SEAL.]

III. BY-LAWS OF THE CORPORATION OF THE MARINE BIOLOGICAL LABORATORY

I. The annual meeting of the members shall be held on the second Tuesday in August, at the Laboratory, in Woods Hole, Mass., at 12 o'clock noon, in each year, and at such meeting the members shall choose by ballot a Treasurer and a Clerk, who shall be, *ex officio*, members of the Board of Trustees, and Trustees as hereinafter provided. At the annual meeting to be held in 1897, not more than twenty-four Trustees shall be chosen, who shall be divided into four classes, to serve one, two, three, and four years, respectively, and thereafter not more than eight Trustees shall be chosen annually for the term of four years. These officers shall hold their respective offices until others are chosen and qualified in their stead. The Director and Assistant Director, who shall be chosen by the Trustees, shall also be Trustees, *ex officio*.

II. Special meetings of the members may be called by the Trustees, to be held in Boston or in Woods Hole at such time and place as may be designated.

III. The Clerk shall give notice of meetings of the members by publication in some daily newspaper published in Boston at least fifteen days before such meeting, and in case of a special meeting the notice shall state the purpose for which it is called.

IV. Twenty-five members shall constitute a quorum at any meeting.

V. The Trustees shall have the control and management of the affairs of the Corporation; they shall present a report of its condition at every annual meeting; they shall elect one of their number President and may choose such other officers and agents as they may think best; they may fix the compensation and define the duties of all the officers and agents; and may remove them, or any of them, except those chosen by the members, at any time; they may fill vacancies occurring in any manner in their own number or in any of the offices. They shall from time to time elect members to the Corporation upon such terms and conditions as they may think best.

VI. Meetings of the Trustees shall be called by the President, or by any two Trustees, and the Secretary shall give notice thereof by written or printed notice sent to each Trustee by mail, postpaid.

Seven Trustees shall constitute a quorum for the transaction of business. The Board of Trustees shall have power to choose an Executive Committee from their own number, and to delegate to such Committee such of their own powers as they may deem expedient.

VII. The President shall annually appoint two Trustees, who shall constitute a committee on finance, to examine from time to time the books and accounts of the Treasurer, and to audit his accounts at the close of the year. No investments of the funds of the Corporation shall be made by the Treasurer except approved by the finance committee in writing.

VIII. The consent of every Trustee shall be necessary to a dissolution of the Marine Biological Laboratory. In case of dissolution, the property shall be given to the Boston Society of Natural History, or some similar public institution, on such terms as may then be agreed upon.

IX. These By-Laws may be altered at any meeting of the Trustees, provided that the notice of such meeting shall state that an alteration of the By-Laws will be acted upon.

X. Any member in good standing may vote at any meeting, either in person or by proxy duly executed.

IV. TREASURER'S REPORT

For the Year Ending December 28, 1912

Receipts

Annual Dues	$ 716.00	
Chemicals	7.83	
Charles R. Crane	16,500.00	
Fire insurance (Botany Building)	995.19	
Mess	10,088.12	
Mess extension	1,007.47	
Miscellaneous:		
Interest on deposits, use of drain, rent of microscopes, telephones, notary fees, etc.	91.48	
Rockefeller Institute	300.00	
Supply Department	13,966.35	
Tuitions	4,875.00	$48,547.44

Payments

Overdraft on December 22, 1911	$ 56.41	
Adminstration (including expenses of treasurer's office)	5,696.29	
Bath house	40.92	
Biological Bulletin (net)	951.05	
Boats	4,452.97	
Carpenter	299.93	
Chemical Department	1,351.66	
Dormitories	385.41	
Fish trap	1,510.02	
Homestead, ice house	206.18	
Homestead, shop	12.30	
Homestead, mess	8,507.02	
Instructors' salaries	3,125.00	
Insurance	4.64	
Interest	150.00	

Library	1,243.09	
Machinery and tools	199.46	
Maintenance of buildings and grounds	2,100.09	
Mess extension	1,749.04	
New laboratory	42.00	
Oil house	49.26	
Pile driver	119.45	
Printing and advertising	40.86	
Real estate	801.00	
Repairs to botany building	187.06	
Scientific apparatus	277.36	
Stone building	7.00	
Store house	896.90	
Sundries	388.72	
Supply department	8,907.65	$43,758.74
Cash on hand December 28, 1912		$ 4,788.70

MARINE BIOLOGICAL LABORATORY
INVESTMENTS

JANUARY 1, 1913

Reserve Fund

Amount of fund December 1, 1899	$4,553.14	
Received from life memberships	600.00	
Income to January 1, 1913	2,516.90	
Gain from sale of securities and rights	372.38	
	8,042.42	
Paid for current expenses of Laboratory	6,000.	$2,042.42
Reserve Fund now consists of the following:		
$3,000 Am. Tel. & Tel. Co. 4s cost	$2,921.25	
6 shs. Am. Smelting & Refining Co. Pfd. cost	732.00	
5 shs. Gen. Electric Co.	756.25	
14 shs. United Shoe Mach. Corp. Pfd. cost	393.75	
Cash	239.17	
	$5,042.42	
Part of the above stocks and bonds are held as collateral for loan of	3,000.	$2,042.42

Library Fund

Amount of fund December 1, 1899	$ 866.15	
Income to January 1, 1913	866.27	
Gain from sale of securities and rights	96.39	$1,828.81
The Library Fund now consists of the following:		
3 shs. Am. Tel. & Tel. Co. cost	$ 383.25	
4/5 of $1,000 Am. Tel. & Tel. Co. 4s cost	799.00	
1 sh. Am. Smelting & Refining Co. Pfd. cost	122.00	
2 shs. General Electric Co. cost	302.50	
5 shs. United Shoe Mach. Corp. Pfd. cost	140.63	
Cash	101.43	$1,828.81

Lucretia Crocker Fund

Amount of fund December 1, 1899	$2,500.	
Income after paying students' fees	643.41	
Sale of rights	8.79	$3,152.20
The Lucretia Crocker Fund now consists of the following:		
18 shs. Vermont & Mass. R. R. Co. cost	$2,416.50	
1 sh. West End Street R'y Co. cost	83.	
1 sh. Am. Tel. & Tel. Co. cost	127.75	
1/5 sh. of $1,000 Am. Tel. & Tel. Co. 4s cost	194.75	
1 sh. General Electric Co.	151.25	
Cash	178.95	$3,152.20

Cash Receipts and Disbursements on Account of Funds Since August 13, 1912

Reserve Fund

Cash on hand August 13, 1912	$ 202.92	
Div. 6 shs. Am. Smelting & Refining Co. Pfd. Sept. 1	10.50	
Div. 6 shs. Am. Smelting & Refining Co. Pfd. Dec. 1	10.50	
Div. 5 shs. Gen. Elec. Co.	10.	
Div. 14 shs. United Shoe Mach. Corp. Pfd.	5.25	$ 239.17

Crocker Fund

Cash on hand August 13, 1912	$ 119.20	
Div. 1 sh. West End St. Ry.	1.75	
Div. 18 shs. Vermont & Mass. R. R.	54.	
Div. 1 sh. Gen. Elec. Co.	2.	
Div. 1 sh. Am. Tel. & Tel. Co.	2.	178.95

Library Fund

Cash on hand August 13, 1912	$ 86.05	
Div. 1 sh. Am. Smelting & Refining Co. Pfd. Sept. 1	1.75	
Div. 1 sh. Am. Smelting & Refining Co. Pfd. Dec. 1	1.75	
Div. 5 shs. United Shoe Mach. Corp. Pfd.	1.88	
Div. 2 shs. Gen. Electric Co.	4.00	
Div. 3 shs. Am. Tel. & Tel. Co.	6.00	101.43
Cash on hand December 28, 1912		$ 519.55

V. THE DIRECTOR'S REPORT.

To the Trustees of the Marine Biological Laboratory:

Gentlemen: I have the honor to transmit herewith a report of the twenty-fifth session of the Marine Biological Laboratory. The attendance of investigators at the Laboratory in 1912 exceeded that of previous years by a considerable number, 93 in 1912 as compared with 82 in 1911, and 62 in 1910. The number of students in the courses was 67 as compared with 65 in 1911 and 64 in 1910. The total attendance was 160 in 1912, 147 in 1911, and 126 in 1910. During part of the season the buildings were uncomfortably crowded; indeed if it had not been for the additional space furnished by the Kidder annex it would have been necessary to turn away a number of investigators. The student accommodations are at present ample and likely to remain so, but the limitation of space assignable to individual investigators, especially in the general research laboratories, is a serious handicap to the best kind of work. For the season of 1913 some additional space will be available, if needed, in the Yacht Club building; but the facilities in this building and in the Kidder annex will be at best makeshifts.

Fortunately, such conditions will not long continue, as the plans for the new laboratory building are now complete, and the building will be erected in the coming summer.

The number of subscribing institutions again showed an increase, from 25 in 1911 to 29 in 1912. In 1907 the number was 16 and the increase since has been steady. The following subscriptions were new: Carleton College, Else Seringhaus Scholarship of Normal College, Laboratory of Comparative Anatomy of Harvard Medical School, University of Texas, and Wabash College. It is gratifying to see this growing recognition by institutions of the value of the facilities offered by the Laboratory; but we must not cease to labor for its ex-

tension, because the Laboratory will be on a sounder basis when a larger number of institutions feel responsibility for their share of its support.

The growth of the Laboratory in numbers and the yearly purchase of houses in Woods' Hole by members of the Laboratory have combined to reduce the living accommodations in Woods Hole for transient workers at the Laboratory below the margin of safety. There is no doubt that if we have even a slight increase of numbers another year some will be unable to secure rooms in the village, and the price of available rooms will become excessive. Last season the Laboratory rented a house for use as a woman's dormitory with accommodations for about 14, and for some years past over 20 men have been accommodated in the stone building. We are face to face with the actual necessity of providing a dormitory for women. Some emergency provision must be made for the summer of 1913, and at the same time we must look beyond this to the necessity of more satisfactory and permanent provision. We cannot expect that the villagers will take care of any increase, because they find it more profitable to rent their houses to families than rooms to detached individuals.

After the erection of the new building it is possible that one of the smaller laboratory buildings might be made over as a dormitory for women; but whether this is desirable or not, it is important that the matter should receive prompt consideration in order that there may be no handicap on the attendance of women at the Laboratory. It is suggested that committees, both of the Board of Trustees and of the Corporation, be organized to consider the problem.

During the past summer the assistant director undertook to collect funds for much needed improvements and enlargement of the mess. Appeals were made to members of the Board of Trustees and of the Corporation and former members of the Laboratory with very gratifying results. There exists to-day, as in earlier periods of the history of the Laboratory, a strong feeling of loyalty and attachment to the interests of the institution, and it is my conviction that this feeling should be organized in some permanent form to serve definite needs of the Laboratory.

Care should be taken that no undue pressure be exerted, and that no one should come to feel his membership in the corporation in any sense a burden; but there can be no doubt that it is possible to avoid this and at the same time to secure effective support for various needs. Moreover, such activities heighten the sense of devotion of those taking part in them. Our organization is primarily coöperative; there should be adequate outlets for all who feel disposed to aid in any way.

Since the last annual report was made death has removed from our number Professor T. H. Montgomery, Jr., clerk of the corporation and ex officio a member of the board of trustees. At the summer meeting of the corporation and board of trustees of the Marine Biological Laboratory the following resolution was adopted:

"On March 19, 1912, Dr. Thomas Harrison Montgomery, Jr., professor of zoölogy in the University of Pennsylvania, clerk of the corporation and a trustee of the Marine Biological Laboratory, died at the early age of 39 years. He was a loyal friend of this Laboratory, with which he had been connected as investigator and instructor for about fifteen years. He was an investigator of high rank, whose discoveries have become a permanent part of biological science; an instructor and organizer of unusual ability; a man of fine instincts and lofty ideals, to whom the 'rare old name of gentleman' applied with peculiar force.

"The corporation and trustees of the Marine Biological Laboratory record their great loss and personal sorrow in his death, and extend to the members of his family deep sympathy in their bereavement."

Professor Montgomery's place in the corporation and board of trustees has been filled by the election of Dr. Gary N. Calkins, of Columbia University. Another vacancy in the board was filled by the election of Dr. H. H. Donaldson, of the Wistar Institute of Anatomy and Biology. To both of these gentlemen we extend out cordial greetings.

The treasurer's report shows a surplus of receipts over expenditures, thanks to the inexhaustible generosity of the president of the board, Mr. Crane. The running expenses were

higher in 1912 than in 1911 owing to (1) the appointment of the assistant director to give full time to the Laboratory, (2) increase in the janitor and collecting service, (3) to slight unavoidable increases in the running expenses of various departments. The receipts from various sources have increased year by year, so that the relation of earned income to total running expenses has not varied much. The following table will be of interest in this connection:

Income.	1909	1910	1911	1912
1. Dues	$ 666.00	$ 606.00	$ 728.00	$ 716.00
2. Misc.	205.44	856.11	122.96	91.48 7.83
3. Supply dept.	8,549.55	9,300.58	10,303.61	13,966.35
4. Mess (net)		551.97	1,111.93	1,581.10
5. Tuition, etc.	3,708.35	4,150.00	4,574.99	5,175.00
Total	13,128.34	15,464.66	16,841.49	20,837.76
Expense, Total	21,585.79	22,547.48	27,929.07	31,526.46
Amount needed to be covered by donations.	8,457.45	7,082.82	11,087.58	10,688.70
Proportion of deficit to total expense	39+%	31+%	39+%	34−%

The total expenses outside of the actual purchase of real estate, building, and operation of the mess are given in these figures. The credits that might naturally be allowed for permanent improvements such as the building of an ice house and work shop and the purchase of the motor boat *Sagitta* in 1911 do not appear.

It is obvious that the expense of operation is rapidly increasing in correspondence partly with the growth in attendance and partly in consequence of the endeavor to furnish more efficient service. The estimates for 1913 show another probable increase of $4,000 to $5,000 in running expenses, and in 1914, with the new building in operation, yet farther increase is inevitable. The growth of the Laboratory entails increased financial responsibility. The only way of meeting the situation and proving equal to the opportunity of scientific service that is ours is to undertake at once to raise an endowment fund of not less than $500,000. With this to rely on the institution could hold permanently all that it has gained. Fortunately, the Laboratory has no debts,

and an emergency could be met to a certain extent by radical retrenchment.

There are appended as parts of this report a list of the staff and of the students and investigators for 1912, together with a tabular view of attendance for the last five years; the list of subscribing institutions, the evening lectures, and the membership of the Corporation.

1. THE STAFF—1912

F. R. LILLIE, DIRECTOR,
Professor of Embryology, The University of Chicago.

GILMAN A. DREW, ASSISTANT DIRECTOR,
Marine Biological Laboratory.

ZOÖLOGY

I. INVESTIGATION

Zoölogy and Embryology

GARY N. CALKINS.....Professor of Protozoölogy, Columbia University.
E. G. CONKLIN.....Professor of Zoölogy, Princeton University.
GILMAN A. DREW.....Assistant Director, Marine Biological Laboratory.
GEORGE LEFEVRE.....Professor of Zoölogy, University of Missouri.
FRANK R. LILLIE.....Professor of Embryology, The University of Chicago.
T. H. MORGAN.....Professor of Experimental Zoölogy, Columbia University.
E. B. WILSON.....Professor of Zoölogy, Columbia University.

II. INSTRUCTION

CASWELL GRAVE.....Associate Professor of Zoölogy, Johns Hopkins University.
RAYMOND BINFORD.....Fellow in Zoölogy, Johns Hopkins University.
A. S. PEARSE.....Associate Professor of Biology, St. Louis University School of Medicine.
BERTRAM G. SMITH.....Graduate Student of Zoölogy, Columbia University.
E. D. CONGDON.....Instructor in Embryology, Cornell University Medical College.
ROBERT CHAMBERS, JR...Graduate Student of Zoölogy, Columbia University.

EMBRYOLOGY

I. INVESTIGATION (See Zoölogy)

II. INSTRUCTION

GILMAN A. DREW.....Assistant Director, Marine Biological Laboratory.

LORANDE L. WOODRUFF..Assistant Professor of Biology, Yale University.

WILLIAM E. KELLICOTT..Professor of Biology, Goucher College.

ROBERT A. BUDINGTON..Associate Professor of Zoölogy, Oberlin College.

PHYSIOLOGY

I. INVESTIGATION

ALBERT P. MATHEWS....Professor of Physiological Chemistry, The University of Chicago.

R. S. LILLIE.....Instructor in Comparative Physiology, University of Pennsylvania.

HAROLD C. BRADLEY....Assistant Professor of Physiological Chemistry, University of Wisconsin.

II. INSTRUCTION

R. S. LILLIE.....Instructor in General Physiology, University of Pennsylvania.

WALTER E. GARREY.....Associate Professor of Physiology, Washington University Medical School.

FRANK P. KNOWLTON....Professor of Physiology, Syracuse University.

EDWARD B. MEIGS.....Associate in Physiology, Wistar Institute of Anatomy and Biology.

PHILOSOPHICAL ASPECTS OF BIOLOGY AND ALLIED SCIENCES

LECTURES

EDWARD G. SPAULDING..Assistant Professor of Philosophy, Princeton University.

BOTANY

GEORGE T. MOORE.....Professor of Plant Physiology and Applied Botany, Washington University.

GEORGE R. LYMAN.....Assistant Professor of Botany, Dartmouth College.

B. M. DUGGAR.....Professor of Plant Physiology, Cornell University.

IVEY F. LEWIS.....Professor of Biology, Randolph-Macon College.

W. J. ROBBINS.....Assistant in Plant Physiology, Cornell University.

LIBRARY

H. McE. KNOWER.....University of Cincinnati, Librarian.

CHEMICAL SUPPLIES

OLIVER S. STRONG.....College of Physicians and Surgeons, New York City, Chemist.

G. M. GRAY.....Curator of Supply Department.

THOMAS M. DOUTHART and JOHN J. MORTON..Collectors in Zoölogy.

O. F. CURTIS.....Collector in Botany, Oberlin College.

JOHN VEEDER.....Cockswain.

2. INVESTIGATORS AND STUDENTS 1912

INVESTIGATORS—1912

ZOOLOGY

BAITSELL, GEORGE A., Assistant in Zoölogy, Yale University.
BECKWITH, CORA J., Instructor in Biology, Vassar College.
BINFORD, RAYMOND, Fellow in Zoölogy, Johns Hopkins University.
BORING, ALICE M., Assistant Professor of Zoölogy, University of Maine.
BUDINGTON, ROBERT A., Associate Professor of Zoölogy, Oberlin College.
CALKINS, GARY N., Professor of Protozoölogy, Columbia University.
CARY, LEWIS R., Instructor in Zoölogy, Princeton University.
CHAMBERS, ROBERT, JR., Associate Professor of Embryology and Histology, University of Cincinnati.
CLAPP, CORNELIA M., Professor of Zoölogy, Mount Holyoke College.
CLARK, ELEANOR LINTON, Special Student, Johns Hopkins University.
CLARK, ELIOT R., Associate in Anatomy, Johns Hopkins University.
CONKLIN, EDWIN G., Professor of Biology, Princeton University.
DEXTER, J. S., Graduate Student, Columbia University.
DREW, GILMAN, A. Assistant Director, Marine Biological Laboratory, Woods Hole, Mass.
EDWARDS, DAYTON J., Tutor in Physiology, College of the City of New York.
GLASER, OTTO C., Junior Professor of Zoölogy, University of Michigan.
GRAVE, CASWELL, Associate Professor of Zoölogy, Johns Hopkins University.
GREGORY, LOUIS H., Instructor in Zoölogy, Barnard College.
HARVEY, E. NEWTON, Instructor in Zoölogy, Princeton University.
HICKERNELL, LOUIS M., Graduate Fellow, Princeton University.
HOGUE, MARY J., Instructor in Zoölogy, Mount Holyoke College.
KELLICOTT, WILLIAM E., Professor of Biology, Goucher College.
KNOWER, H. McE., Professor of Anatomy, University of Cincinnati.
LEWIS, MARGARET REED, 1931 East 31st Street, Baltimore, Md.
LEWIS, WARREN H., Associate Professor of Anatomy, Johns Hopkins University.
LILLIE, FRANK R., Director, Marine Biological Laboratory, and Professor of Embryology, University of Chicago.
LOEB, LEO, Director, Department of Pathology, Barnard Free Skin and Cancer Hospital, St. Louis, Mo.
LUND, ELMER J., Bruce Fellow, Johns Hopkins University.
MALONE, EDWARD F., Assistant Professor of Anatomy, University of Cincinnati.
MORRILL, CHARLES V., Instructor in Anatomy, University and Bellevue Hospital Medical College, New York City.
MORGAN, T. H., Professor of Experimental Zoölogy, Columbia University.
NOWLIN, NADINE, Instructor in Zoölogy, University of Kansas.

ORCUTT, ALFRED W., Fellow in Zoölogy, University of Illinois.
PAPPENHEIMER, ALWIN M., Associate in Pathology, Columbia University.
PATTERSON, JOHN T., Adjunct Professor of Zoölogy, University of Texas.
PEARSE, A. S., Assistant Professor of Zoölogy, University of Wisconsin.
SMITH, BERTRAM G., Assistant Professor of Zoölogy, State Normal College, Ypsilanti, Mich.
SPAULDING, EDWARD G., Assistant Professor of Philosophy, Princeton University.
STOCKARD, CHARLES R., Professor of Anatomy, Cornell Medical College.
STRONG, OLIVER S., Instructor in Anatomy, Columbia University.
WIEMAN, H. L., Assistant Professor of Zoölogy, University of Cincinnati.
WILLIAMS, L. W., Instructor in Comparative Anatomy, Harvard Medical School.
WILSON, E. B., Professor of Zoölogy, Columbia University.
WOODRUFF, L. L., Assistant Professor of Biology, Yale University.

PHYSIOLOGY

BANCROFT, FRANK W., Associate, Rockefeller Institute for Medical Research.
BRADLEY, HAROLD C., Assistant Professor of Physiological Chemistry, University of Wisconsin.
DONALDSON, H. H., Professor of Neurology, Wistar Institute of Anatomy and Biology.
EWALD, W. F., Fellow, Rockefeller Institute for Medical Research.
GARREY, W. E., Associate Professor of Physiology, Washington University Medical College.
KITE, GEORGE L., Fellow in Pathology, Sprague Institute, University of Chicago.
KNOWLTON, FRANK P., Professor of Physiology, Syracuse University.
LILLIE, RALPH S., Assistant Professor of Experimental Zoölogy, University of Pennsylvania.
LOEB, JACQUES, Rockefeller Institute for Medical Research.
LYON, E. P., Professor of Physiology, St. Louis University.
MEIGS, EDWARD B., Fellow in Physiology, Wistar Institute of Anatomy and Biology.
ROSENOW, EDWARD C., Assistant Professor of Medicine, Rush Medical College.
WASTENEYS, HARDOLPH, Associate, Rockefeller Institute for Medical Research.
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BOTANY

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STUDENTS

1912

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NOBLE, ARLYLE, Smith College, Northampton, Mass.
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STONE, MABEL A., Instructor in Botany, Wellesley College.
THOMAS, CECIL C., Instructor in Botany, Wabash College.
WEEKS, LUCY M., Student, Oberlin College.
WESTON, WILLIAM H., JR., Graduate Student, Harvard University.
WOOD, ISABELLE T., Student, Vassar College.

3. TABULAR VIEW OF ATTENDANCE

	1908	1909	1910	1911	1912
INVESTIGATORS—Total	52	66	62	82	93
Occupying Rooms					
Zoölogy	32	39	33	42	44
Physiology	6	7	11	18	14
Botany	8	4	9	8	10
Occupying Tables					
Zoölogy	6	14	6	12	21
Physiology		2	2	2	2
Botany					2
STUDENTS—Total	48	63	64	65	67
Zoölogy	19	36	31	26	24
Embryology	15	12	10	20	15
Physiology	3	9	5	6	11
Botany	11	6	17	13	17
TOTAL ATTENDANCE	100	129	126	147	160
INSTITUTIONS REPRESENTED—					
Total					57
By Investigators	25	27	26	37	43
By Students	26	20	24	31	36
SCHOOLS and ACADEMIES REPRESENTED					
By Investigators	2	3	5	3	2
By Students	3	11	6	9	1

4. SUBSCRIBING INSTITUTIONS, 1912

Carleton College.
Columbia University.
Dartmouth College.
Else Seringhaus Scholarship of Normal College, New York.
Goucher College.
Harvard Medical School, Laboratory of Comparative Anatomy.
Lucretia Crocker Scholarship—Boston Public Schools.
Milton Hersey Scholarship—McGill University.
Mount Holyoke College.
Oberlin College.
Princeton University.
Rockefeller Institute for Medical Research.
Sheffield Scientific School, Yale University.
Smith College.
Syracuse University.
University of Chicago.
University of Cincinnati.
University of Illinois.
University of Kansas.
University of Michigan.
University of Pennsylvania.
University of Rochester.
University of Texas.
Vassar College.
Wabash College.
Western College for Women.
Wellesley College.
Williams College.
Wistar Intsitute of Anatomy and Biology.

5. EVENING LECTURES, 1912

PROF. W. E. CASTLE....."Unit Characters in Heredity" Friday, July 5.

PROF. CHARLES S. MINOT.."Senescence".....Tuesday, July 9.

PROF. FRANK M. CHAPMAN."A Natural History Reconnaissance in Mexico"....Friday, July 12.

DR. GEORGE H. SHULL....."The Bearing of Cross and Self-Fertilization on Heredity and Evolution".....Tuesday, July 16.

PROF. H. E. CRAMPTON....."A Biological Reconnaissance in South America,"...Friday, July 19.

DR. R. S. LILLIE....."The Role of Membranes in Cell-Processes"....Tuesday, July 23.

DR. C. M. CHILD....."Certain Dynamic Factors in Reproduction and their Significance".....Friday, July 26.

PROF. E. G. CONKLIN....."The Mechanism of Cell-Division".....Tuesday, July 30.

PROF. W. L. TOWER....."Experimental Transmutation of Specific and Generic Characters".....Friday, Aug. 2.

PROF. E. O. JORDAN....."The Spread of Typhoid"... Tuesday, Aug. 6.

PROF. CHARLES E. BESSEY."The Phyletic Arrangement of Flowering Plants"...Friday, Aug. 9.

6. MEMBERS OF THE CORPORATION

Life Members, 1912

Allis, Mr. E. P., Jr., Palais Carnoles, Menton, France.
Andrews, Mrs. Gwendolen Foulke, 821 St. Street, Baltimore, Md.
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Kidder, Mr. Nathaniel T., Milton, Mass.
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WILSON, PROF. W. P., Philadelphia Museum, Philadelphia, Pa.

Members, August, 1912

Abbott, Prof. J. F., Washington University, St. Louis, Mo.

Abbott, Margaret B., Bennett School, Millbrook, New York.

Adams, Dr. C. F., University of Arkansas, Fayetteville, Ark.

Addison, Dr. W. H. F., University of Pennsylvania, Philadelphia, Pa.

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Bigelow, Prof. R. P., Massachusetts Institute of Technology, Boston, Mass.

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NACHTRIEB, DR. H. F., University of Minnesota, Minneapolis, Minn.
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